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A TREATISE

ON THE

LAW OF IRRIGATION

AND WATER RIGHTS

AND THE ARID REGION DOCTRINE OF APPROPRIATION OF WATERS

AS THE SAME IS IN FORCE IN THE STATES OF THE ARID AND SEMI-ARID REGIONS OF THE UNITED STATES; AND ALSO INCLUDING AN ABSTRACT OF THE STATUTES OF THE RESPECTIVE STATES, AND THE DECISIONS OF THE COURTS RELATING TO THOSE SUBJECTS.

BY

CLESSON S. KINNEY

OF THE

SALT LAKE CITY BAR.

SECOND EDITION

IN FOUR VOLUMES.

REVISED AND ENLARGED TO OCTOBER 1, 1912.

VOLUME I.

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DEDICATION OF THE FIRST EDITION

TO THE

HON. THOMAS M. COOLEY, LL. D.,

WHO EMINENTLY ADORNS AMERICAN JURISPRUDENCE, IN THE CAPACITY OF

JUDGE, AUTHOR, AND TEACHER,

AND IN EACH OF WHICH HE HAS NO SUPERIOR,

THIS WORK IS DEDICATED

AS AN EXPRESSION OF ADMIRATION AND RESPECT, BY ONE WHO HAS ENJOYED THE GOOD FORTUNE OF BEING BOTH HIS PUPIL AND FRIEND.

271537

PREFACE TO THE FIRST EDITION.

The present work has been written with the hope that it may prove serviceable to the profession in their investigation of a subject comparatively new in the history of American jurisprudence. Irrigation was born from the absolute necessities of the settlers of an arid region. Although practiced in the United States by an English speaking people but about fifty years it has been the principal means of the settlement and development of that portion of our country west of the 100th meridian, until today it has become a subject of paramount importance to the whole country.

Involving, as it does, a use of water based upon the principle of priority of appropriation—which doctrine was not recognized by the common law—irrigation has caused numberless controversies concerning water rights. As the result of these contentions, a mass of court decisions and statutory law upon the subject has been evolved which governs the subject of waters in the arid region.

Part One of this volume is devoted to a general discussion of the nature and history of irrigation and the general laws that govern the subject in the arid region.

As the character of irrigation law depends largely upon the physical and topographical conditions of the State or Territory wherein the same has been evolved and is in force, in order to understand its development the author has very briefly described the general condition of the various States and Territories in Part Two. This part also contains an abstract of the statutory laws and the construction of those laws by the courts.

CLESSON S. KINNEY.

SALT LAKE CITY, UTAH,
February 23, 1894.

PREFACE TO THE SECOND EDITION.

Probably no other industry in this country has developed to the extent that irrigated agriculture has developed during the last twenty years, or since the first edition of this work was written. Correspondingly, the laws upon the subject of the use of water for irrigation and all beneficial uses and purposes may be said to have developed.

In the States, since the first edition of this work was written, the irrigation district law of California, which was then hanging in the balance, has been declared constitutional by the Supreme Court of the United States. As a result, nearly every Western State has adopted an irrigation district law similar to that of California, as one of its systems of laws governing and controlling waters by local public corporations, and the State courts have invariably held that these laws were constitutional.

Again, during the period of 1901 to 1909 many of the States through their legislatures, have adopted irrigation or water codes, usually tending toward a system of State control of the waters within their boundaries and the appropriation, regulation, and distribution through State officials.

Furthermore, thousands of cases have been decided by the courts of last resort of these Western States, deciding or attempting to decide many propositions as they were presented and new phases of rights to waters.

In the meantime Congress has also been busy. The Carey Act was passed in 1894, by which, through the joint efforts of the United States, the respective States, and private corporations, thousands of acres have been reclaimed. Again, in 1902, the National Reclamation Act was passed and since that time has been in force. Through the Reclamation Service, under this Act, many thousands of acres are annually being reclaimed, and also many new features have been added to the law.

The law of subterranean waters, especially as to artesian or catchment basins, may be said to be at the present time in the period of transition from the strict rule of the common law, that all such waters belong to the owner of the soil where the same might

be found, to the law of correlative rights or the rights of all of the owners whose lands overlie these waters, to their proportion of the same.

From the above it may be seen that not only have many new laws been added to the law of water and water rights, but also many new features have been added to the old laws. Therefore, the present work has been entirely rewritten to meet the exigencies of the case. No excuse is offered for making the present edition in four volumes as it is fully warranted by the scope and importance of the subject. Upon the other hand, an apology ought to be offered for not revising the old edition about ten years ago.

In the present edition, we have aimed to make the work complete and exhaustive upon every phase of the subject and, by way of comparison, world wide in its application. Our abstract of foreign methods and laws is considered a valuable addition to the work.

The author having been in the active practice of law for over twenty-five years, and particularly in cases involving many of the subjects discussed, the main portion of the work was written from that standpoint and for the use of the courts and practitioners.

The author offers no apology for submitting this work to the profession, already over-burdened with law books. A great deal of labor and pains have been expended to make the work as complete as possible, and while it is too much to expect that no errors can be found, it is hoped that it will result in lightening the labors of those who are working along the lines of the subjects under discussion. Should the work accomplish this, it will compensate in a large measure for the time and toil expended upon it by the author.

CLESSON S. KINNEY.

Dated at SALT LAKE CITY, UTAH,
September 25, 1912.

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KINNEY

ON

IRRIGATION AND WATER RIGHTS.

SECOND EDITION—VOLUME ONE.

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§ 38. The drainage of irrigated lands or lands affected by irrigation.
§ 39. Legal rights of the irrigator and the owner of irrigation projects.

§ 1. **General scope of part and chapter.**—The economic importance of irrigation to the whole country is not well understood by the people generally; and, except among those who are especially interested in the subject, there is very little knowledge, and that of the most general kind. In this and the following chapter, we will discuss largely the economic side of the question; and in this chapter, irrigation as related to the many important subjects and industries of the country, and its many methods. In the following chapter, forests and their relation to stream flow will be discussed; the waters of which streams are used for the many necessities and enterprises such as domestic, irrigation, navigation, and the many useful purposes to which water is applied. We will also discuss the many disastrous results to the country, in soil wash, flooding of lower lands, in the failure of inland navigation, and other kindred subjects, by not more fully conserving our water supply for use, but permitting the waters to run to waste at will, and thereby causing such results.

In the discussion of so many of these subjects in these two chapters, our space to each is necessarily limited. However, for those who desire to investigate further, will be found voluminous references to the authorities in our foot notes.

§ 2. **Our fresh water resources.**—The sole source of our fresh water supply is from precipitation, which comes to the earth from the clouds either in the form of rain or snow. From this source, our running, standing, and subterranean waters of all classes are derived. The habitability of the country depends on these waters.

Through the observations and measurements of the United States Weather Bureau, at some 4,000 stations scattered throughout all sections of the country, our annual precipitation is known more accurately than that of any other equal area on the globe. The quantity of water falling upon the land averages 200,000,000,000,000 cubic feet per annum; and, including that falling on water areas, it is 215,000,000,000,000 cubic feet per annum. This is equal to 6,088,236,690 kilosteres,[1] 5,000,000,000 acre-feet or 1,500 cubic miles. The volume is that of ten rivers the size of the Mississippi.

But this precipitation is not distributed equally over the entire surface of the country. The proximity to the sea, the mountain ranges, the prevailing winds, and many other conditions peculiar to certain sections of the country, cause a very unequal distribution of the rainfall. And it has been ascertained that the annual rainfall[2] on the more humid two-fifths of the country east of the 95th meridian is nearly 48 inches; the quantity of about 140,000,000,000,000 cubic feet. On the semi-arid fifth of our area, or between the 95th and 103d meridians, the rainfall averages 30 inches and aggregates over 40,000,000,000,000 cubic feet. The rainfall on the western two-fifths of the country, including what is known as the arid region of the United States and concerning which this work largely relates, averages only about 12 inches per annum, or some 35,000,000,000,000 cubic feet. This again is by no means distributed equally over this area, and varies in different sections from five to six inches to amounts equaling the rainfall in some of the more humid sections.

Generally speaking, the distribution of the total rainfall is as follows: Over one-half is evaporated; about one-third flows into the sea; the remaining one-sixth is either consumed or absorbed. These portions are called, respectively, the "fly-off," the "run-off," and the "cut-off," and are partly interchangeable.

The fly-off influences the climate, and thus affects agriculture and other industries in all parts of the country. Except in a moderate degree through the management of the land surface, it is beyond artificial control.[3]

The run-off is available for water supply for various purposes,

1 A kilostere of water is equivalent to a cube of 32.8 feet.

2 And in this we include the snow.

3 For evaporation and the prevention of the same, see Secs. 26, 27.

such as domestic use, irrigation, navigation, and power. It is now controlled in small part by artificial means, and may be wholly controlled by proper means.[4] The run-off is increasing yearly, with deforestation of the drainage basins along the sources of the rivers and streams.[5]

The cut-off, or the remainder of the rainfall under this classification, is either consumed in plant growth and other chemical combinations, or it permeates the deeper strata of the earth and passes subterraneously into the sea. It is now partially controlled by human agency, chiefly through farming and forestry; and this control may be much increased.[6] With this understanding of the rainfall of this country and its general distribution by Nature, we will discuss in the remaining portion of this chapter the economic questions as relating to the regulation and distribution of our water supply through the agency of man, and more especially by the means of the irrigation of arid lands.[7]

§ 3. **"Irrigation"—Definitions.**—Irrigation is defined as the "act or process of irrigation, or state of being irrigated." "The supplying of water to land by canals, ditches, etc.; the operation of causing water to flow over land, for nourishing plants." "A refreshing or making fertile as if by watering."[1]

The word "irrigation" in its primary sense, means any kind of watering or moistening, yet, in common parlance, its meaning is ordinarily restricted to the "watering of lands for agricultural purposes."[2]

As defined in the Australian Water Act, 1905: "'Irrigation' means any method of causing water from a stream or channel to flow upon and spread over land for the purpose of tillage or im-

4 See Secs. 11-15.

5 For forests and their relation to stream flow, see Chap. 2, Secs. 40-62.

6 See article by W. J. McGee, Secretary, Section of Waters, Vol. 1, Report of the National Conservation Commission, 1909, pp. 39-49, in which the above data was furnished by Willis L. Moore, Chief of the United States Weather Bureau.

See, also, Distribution of the Rainfall, by Henry Gannett of the U. S. Geological Survey, Vol. 2, pp. 10-12, Report of the National Conservation Commission, 1909. Also, Water Circulation and Its Control, by Bailey Willis, Vol. 2, p. 687, same report.

7 For the relation of forests to stream flow, see Chap. 2, Secs. 40-62.

1 Webster's New. Int. Dict., 1911, sub.: Irrigation.

See, also, Am. & Eng. Encyc. of Law, 2d Ed., sub.: Irrigation. Bouvier's Law Dict., sub.: Irrigation.

2 Cent. Dict., sub.: Irrigation.

provement of pasture, or of applying water to the surface of the land for the like purposes."[3] It is a method of producing or increasing fertility in dry soils by an artificial supply of water, conducted over the lands by means of ditches or trenches, or by inundation at stated periods. Although the term in its primary sense is defined to be any sprinkling or watering, it has an agricultural or special signification. As stated by the Colorado court in construing the meaning of the term as used in the Colorado Acts of 1879 and 1881, which provided for a system of procedure for determining the priority of rights to the use of water for irrigation, between the owners of ditches, canals, and reservoirs taking water from the same natural stream:[4] "The word 'irrigation,' in its primary sense, is defined 'a sprinkling, or watering'; yet, according to the best lexicographers, it has an agricultural or special signification: 'The watering of lands by drains or channels.' Worcester. 'The operation of causing water to flow over lands for nourishing plants.' Webster. Considering the history of Colorado, the nature of its soil and climate, its constitutional and legislative enactments, as well as the decisions of our courts, we have no hesitation in saying that our legislators used the term 'irrigation' in the acts under consideration according to the common parlance of our people—in its special sense—as denoting the application of water to lands for the raising of agricultural crops and other products of the soil."[5]

Again, in a Nebraska case, in construing the use of the word in the title of the Act of March 27, 1889, entitled, "An act to provide for water rights and irrigation, and to regulate the right to the use of water for agricultural and manufacturing purposes," it was said: "The word 'irrigation,' as employed in the title of the act under consideration, is apparently used in its popular sense, and denotes the application of water to land for the production of crops."[6] The method of obtaining the

[3] Water Act Australia 1905, No. 2016, 12th December, 1905, Sec. 3.

For irrigation in Australia, see Chap. 6, Secs. 119-130.

[4] For the adjudication of water rights in Colorado, see Parts 13, 14.

[5] Platte Water Co. v. Northern Colo. Irr. Co., 12 Colo. 525, 21 Pac. Rep. 711, 2 Denver Leg. News, 201, and also holding that "The use of water for the purpose of irrigation clearly implies the means of conducting it to the land to which it is applied."

[6] Paxton & Hershey etc. Co. v. Farmers' etc. Co., 45 Neb. 884, 64 N. W. Rep. 343, 29 L. R. A. 853, 50 Am. St. Rep. 585.

water from the natural stream for the purpose of applying it to the land has nothing to do with the signification of the word. The water may be taken out by the means of ditches or canals or it may be raised by the means of pumps. As was said in a California case of Charnock v. Higuerra[7] relative to the meaning of the words "irrigate" and "irrigation," the court said: "So far as we can understand, this argument is based on the meaning of the word 'irrigate,' which counsel contends is 'to convey water by ditches,' and on the alleged universal custom in the past to employ only such means in irrigation. As to the meaning of the word 'irrigation' counsel cites some doubtful passages from civil law writers; but it is evident that this court, in holding, as it has repeatedly held, that riparian proprietors have the right to use a reasonable proportion of the water of the stream to irrigate their lands, used the term in no such restricted sense. The Latin word from which it is derived means primarily, to convey waters to or upon anything, and, more generally, to wet or moisten anything; and the ordinary definition in our language is to water lands, whether by channels, by flooding, or simply by sprinkling. The mere method of obtaining the water with which to irrigate *has nothing to do with the process of irrigation, or the meaning of the word.*" Regarding the term "irrigation purposes" or "purposes of irrigation," it is held by the Washington court that it "is a common expression in the legislation of this State, and has acquired a well-defined meaning, which is synonymous with 'agricultural purposes,' or, at least, the former is included within the latter."[8]

§ 4. Nature and importance of irrigation.—The moistening, enriching, or improving of land, for agricultural purposes by

[7] 111 Cal. 473, 44 Pac. Rep. 171, 32 L. R. A. 190, 52 Am. St. Rep. 195.

[8] State v. Tiffany, 44 Wash. 602, 87 Pac. Rep. 932.

See, also, for the appropriation of water for irrigation, Secs. 585-756.

See, also, Rodgers v. Pitt, 129 Fed. Rep. 932; Sayre v. Johnson, 33 Mont. 15, 81 Pac. Rep. 389; Kleinschmidt v. Greiser, 14 Mont. 484, 37 Pac. Rep. 5, 43 Am. St. Rep. 652; Pyke v. Burnside, 8 Idaho, 487, 69 Pac. Rep. 477; Walsh v. Wallace, 26 Nev. 299, 67 Pac. Rep. 914, 99 Am. St. Rep. 692; Millheiser v. Long, 10 New Mex. 99, 61 Pac. Rep. 111; Smyth v. Neal, 31 Ore. 105, 49 Pac. Rep. 850; Power v. Switzer, 21 Mont. 523, 55 Pac. Rep. 32; Basey v. Gallagher, 87 U. S. 20 Wall., 670, 22 L. Ed. 452, 1 Morr. Min. Rep. 683.

means of the application of water, is a subject of enormous importance throughout a great part of the globe. In some parts, Nature alone applies this powerful means of improvement. In others, it is effected for the most part by Nature, occasionally or partially assisted by human skill or labor. Again, in other parts, irrigation as a mode of improvement upon Nature's effort is effected principally by the skill and efforts of man. In all cases, this agency of water, skillfully applied, is more or less useful, according to the circumstances of the case, and the nature and character of the soil and climate where it is so applied. It may be used for ameliorating the soils of different characters, and increasing the amount of their products, as well as adding to the forms of plant life. The tropical rivers annually convey to the lower plains through which they flow immense supplies of enriching deposits, which nourish the products of the soil, or which tend to form and enrich those vast savannahs which occur in those parts. Again, in the warm but more temperate climates, there are immense tracts of land, which, for native vegetation, have only here and there patches of greasewood, sage brush, or mesquite, and which, if not irrigated, except for small value for grazing purposes, so far as any use to civilization is concerned, might as well be wholly barren. Instructed by Nature and educated by experience in the use and application of this element, water, for ameliorating the soil, mankind has already felt its great value and importance from the equator to nearly the 60th degree of north latitude, and, extending in a more limited scale partly into the southern temperate zone. The periodical rains within the tropics are not sufficient, in that burning climate, to nourish plant life and to raise crops necessary to support the population, had not Nature by means of her mighty rivers and streams come to their aid, and if art and labor were not also employed in irrigating and fertilizing vast tracts of land. Even in the vineyards, orchards, and fields in the milder climates of Italy and France, immense profits and advantages are derived from this mode of improvement and cultivation by the judicious artificial application of water to the soil. Irrigation, when properly conducted with care and forethought, has a tendency to improve the soil as well as the climate of the surrounding country where it is practiced, while at the same time the element of the water itself is directed to purposes most useful and profit-

able to mankind. The advantages of this mode of improvement are of course greatest in populous districts, where a small amount of land owned by one person may be brought under a very high grade of intensive cultivation and be made productive of more prolific crops and of a superior value. But, upon the great plains and high plateaus of the arid region of the United States, and where the population is even as yet exceedingly sparse, water is of the utmost value wherever it can be directed safely for irrigation purposes.[1]

§ 5. **"Desert lands" and "arid lands" distinguished.**—A great deal has been written and said about the "desert lands" of the Western part of this country, especially in the early histories of this country, that the facts do not bear out. This has led to a misapprehension, especially in the East, as to the true condition of the West. The early geographies of our boyhood days had great areas of land scattered throughout all of this Western country designated as "desert." It is true that in some isolated portions of the West, for instance in western Utah and in southeastern California, there may be tracts of land which may be called desert in the strict sense of the term. But, in the main, the statements made in our early histories and geographies, in the light of more recent development, as to the greater portion of this Western country being desert, are about as true as were the statements made by Daniel Webster in his "howling wilderness" speech. He used this language as to the western territory which we acquired from Mexico: "What do you want of that vast and worthless area, that region of savages and wild beasts, of deserts, of shifting sands and whirling wind, of dust, of cactus and prairie dogs? To what use could we ever hope to put those great deserts and those endless mountain ranges, impenetrable and covered to their very base with eternal snow? What can we ever do with the Western coast, a coast of 3,000 miles, rockbound, cheerless, and uninviting?" It may be true, and it probably is, that Mr. Webster, when he made this speech, believed in the then popular notion that the Western portion of this country was one vast expanse of mountain and desert. Even Congress

1 For the history of Irrigation, see Chap. 3, Secs. 63-87.
For the advantages of irrigation, see the last edition of Irrigation Farming, by Lucius M. Wilcox, 1910, Chap. 2, pp. 12-21.

has unfortunately aided in this popular notion, by repeatedly referring to these Western lands as desert lands. For example there is the "Desert Land Act,"[1] and the many Acts for the reclamation of "desert lands," hereinafter discussed in this work. The lands referred to in these Acts are not desert lands. They have as rich and enduring soil as any lands on earth, and these Acts of Congress themselves go to show that they are not desert, by providing for their reclamation by the means of irrigation. It is true that many of these lands in their natural state may seem to the Eastern passenger, from the car window, to come within his definition of desert lands. They are mostly covered with a natural growth of sage brush, greasewood, mesquite or some of the other of the many thousands of forms of wild plant life common to the West. But, where these wild plants grow without the artificial application of water, it is a sure sign that the soil producing them is rich; and the heavier the growth usually the richer the soil. By irrigation, anything which can be raised in that particular climate can be grown upon these lands. This is also further illustrated by the many thousands of acres of this land which, in the more recent years, has been successfully cultivated without irrigation under the modern methods of scientific "dry farming."[2] To find desert land, in the strict sense of the term, one must look for land absolutely without plant life.

§ 6. **Drought and aridity.**—Although the great mass of the Western lands can not be described as desert lands, in the strict sense of the term,[1] the most of them are subject to great drought and aridity. Drought is defined as, "dryness; want of rain or water; such dryness of weather or climate as affects the earth, and prevents the growth of plants; aridity."[2]

Drought has also been described by a modern poet. And, although a law text book is hardly the place for poetical quotations, this is so applicable to the subject under discussion in this section that we will take the liberty to indulge in this:

> The road is drowned in dust; the winds vibrate
> With heat and noise of insect wings that sting
> The stridulous noon with sound; no waters sing;

1 See Desert Land Act.
2 See Dry Farming.

1 See Sec. 5.
2 Webster's New Int. Dict., 1911, sub.: Drought.

Weeds crowd the path and barricade the gate.
Within the garden Summer seems to wait
Among her flowers, dead or withering;
About her skirts the teazel's bristles cling,
And to her hair the hot burr holds like hate.
The day burns downward, and with fiery crest
Flames like a furnace; then fierce night falls
Dewless and dead, crowned with its thirsty stars:
A dry breeze sweeps the firmament, and west
The lightning leaps at flickering intervals,
Like some caged beast that thunders at its bars.

—By Madison Cawein.

The average rainfall upon the most of the arable lands in the West is small as compared to that in the Eastern and more humid portions of this country. But, upon the other hand, all portions of the country are subject more or less at times to drought. There is no way of preventing it except by having a plentiful supply of water obtained from the streams and other natural sources of supply and available works, so that the water can be artificially applied, when these periods of drought occur. This is always the case in the irrigated portions of our country, but it is seldom the case in the Middle West or in the Eastern portions. The people there have never acquired the habit of "making it rain with a spade." Therefore, even these regions are, at times, subject to long periods of drought, from which there can be no protection, for the reason that the necessary works to apply the water artificially have never been constructed. And, at these times, the only crop which can be successfully raised is the crop of despair, and of this there is, at times a distressing over-production. In the West it is different. The hotter and drier the weather, the greater will be the plant growth; provided always, that there is an ample supply of water artificially applied to stimulate that growth. And, as it is always dry here during the summer season, the necessary works are already constructed, or are rapidly being constructed, and when completed are always maintained in such a condition that they may be immediately utilized when they are needed. Many of the farmers of the arid West prefer that there should be no rainfall during the summer or cropping season, but that all moisture be applied by means of irrigation. They may then turn on the water or withhold it as is thought best for the particular crop. By this method the water is also applied directly to the roots of

the plants. Then, again, a heavy rainfall is decidedly injurious to some species of plants. However, science, in even its wildest flights, has not been able to regulate the rainfall to any great degree.

§ 7. **The value of irrigation.**—It is not always an easy matter to convince mankind how much is really within the power of human skill and industry. In one age, it is impossible to make men realize what the possibilities of the next generation may be. The first settlers in the American colonies would not have then believed, had it been pointed out to them, what improvements, even in the climate, were to follow the draining and cultivation of their lands after the forests had disappeared. Undoubtedly many ages elapsed before the people of Egypt were capable of duly appreciating the full value of the flood of the Nile, and of turning its enriching water to the utmost possible advantage. The treatment and cultivation of the various kinds of soils, the enriching the same by artificial application of silted water, the best application of industry and skill in the methods by which this work is to be performed, and the selection of the various crops best adapted to the different soils, the most economical and careful methods of diverting, conducting, and applying the water to the land, have required time and patience and the study of the best minds of the scientific methods of this and foreign countries, both ancient and modern. All this as it appears today is embraced in one vast system of modern cultivation of the soil, until irrigation is a part of an extensive national economy, embracing the husbandry of nearly every country. In this country, in the present age, by this means, immensely increased crops of all kinds have been raised, even in regions which are semi-arid, and localities which were formerly marked as "desert lands" have been reclaimed and made possible for the habitation of man. An ever increasing population, coming from the cities and the more congested sections, to the localities irrigated have at the same time furnished the labor necessary and the markets for the crops produced.

§ 8. **Irrigation enterprises and mistakes which have been made.**—Upon the other hand, it can not be denied but that mistakes have been committed in the appliance and practice of this

art. Mistakes have been made in its practical workings, mistakes have been made in legislation, and by the courts in construing such legislation. It has been tried in situations where Nature did not favor success, and it has been employed in order to force a product for which there was not an adequate demand. Engineers have miscalculated, and the works constructed under their supervision have gone out at the first flood. Settlers have failed to come and settle under the works as fast as it was anticipated that they would. All this or other misfortunes have led to the ruin of enterprises, and loss to the stockholders and bondholders. And, in many of such cases, or similar ones, the failure has been most unjustly attributed to the art of irrigation itself, when, in fact, it arose from the errors in judgment or foresight upon the part of those who conducted the operations. But without the requisite skill and attention, it is evident that no undertaking can prosper. Errors, therefore, which occur from these causes, ought in no degree to bring discredit on the art of irrigation itself.

Although irrigation projects, carefully instituted and conservatively conducted, are now among the best in the country for legitimate investment, in some localities there was a time when the wild-catter and the speculator, ever watchful for their prey, organized great corporations, sold their stock and bonds in the financial market, and that, too, when the companies did not have the title to one drop of water to run in their canals or reservoirs, if indeed their works were ever constructed except on paper, and also where there were no irrigable lands to which the water could be successfully applied. Even the Wright irrigation district law of California was overworked, for a time, in that State. A number of schemes under the Carey Act also failed. About twenty years ago many companies went into the hands of receivers from various causes; of course, with great loss to those who had invested their money in the same. Settlers were also induced to take up lands under these projects under the promise that water was either then available or would be at a certain time. Many, owing to long delays, in securing the necessary water to cultivate their lands, abandoned them and went elsewhere. For a time, these failures naturally gave all irrigation projects a backset, especially in the financial world. It was hard to sell stock or bonds in even legitimate and worthy enterprises. But

this condition was only temporary. By careful legislation for State supervision upon the part of all the States where these enterprises were being conducted, the wild-cat enterprises have been practically eliminated from operation in all portions of the West. Then, again, by the United States Government taking the subject in hand, and itself constructing enormous irrigation systems, the days of the wild-cat have practically ended along these lines. By having a rival in the National Government in these enterprises, private parties are compelled to have something of substantial value to offer both to capital and to the settlers.

§ 9. **Effect of irrigation upon the individual.**—Upon the question of economics, one of the greatest benefits of irrigation is upon the individual whose home is in an irrigated section. There was a time, and that time has not passed in some portions of the country, when the farmer was deemed a sort of an isolated personage, dwelling apart from others, and having none of the conveniences, and much less the luxuries, of modern life. He was looked upon with a sort of pity, with the idea that probably the best that he could do was to spend his life upon the farm. His children have grown up; and, seeing the disadvantages of such a life upon the farm, have gone to the cities, which already had a too dense and an over-congested population.

Here, in the West, since the introduction of irrigation projects, all this is changed, or being rapidly changed. Owing to the fact that a small farm well irrigated and cared for will support a family better than a larger one without irrigation, the farmers have nearer neighbors and live together in "farming neighborhoods," or "farming communities." This is beneficial for many reasons. In the first place, "man is a sociable animal," and to live separate and apart from his fellow man is not his natural condition. Under many of these irrigation projects the farmers live in small cities or towns, the land which they cultivate lying at some distance. The average irrigation farmer, if he has been upon his land for some time, usually has a good house, oftentimes of brick or stone, substantial barns and outhouses, electric lights, a telephone, daily rural mail delivery, and many of the conveniences that are not found in city homes. His electric lights are often furnished by the same company from which he secures his water for irrigation; so, too, his telephone, with connections with long distance

lines. By living in communities, he has also within reasonable distance the public school for his children and oftentimes a high school; he has also churches and places of entertainment, stores, banks, and other business houses, where he can dispose of his products and transact his other business. If he is a thrifty man, he ordinarily has money in the bank or loaned out, has his automobile, and is able to purchase other luxuries that are entirely beyond the means of the ordinary city man. And, above all, he is absolutely independent as to how he is to secure a living for himself and his family. In fact, in the irrigated regions of the country, "the poor but honest farmer," as a species, is rapidly becoming extinct, and in his place has come the educated forehanded gentleman, who lives in the country simply because he prefers it, and can secure there better advantages and a more wholesome life for himself and family than he can secure in a large city. Take the same man in the city, and perhaps he might have been able to hold down a clerkship or some mechanical position in some establishment, or he might have attained to the position of a motorman or a conductor on the street railroad. In any one of these positions, it would have been at a meagre salary, and he would have had a constant struggle to "keep the wolf from the door," and have been absolutely deprived of all luxuries, and, oftentime, of the bare necessities of life. I may be thought by some to have overdrawn the picture. But those who are at all familiar with a well developed irrigated region, will bear me out in these statements. And those who are at all familiar with the life of the average clerk, mechanic, or artisan in the city, know that the remarks as to them are understated.

Since writing the above our attention has been called to that most excellent work by Mr. Lucius M. Wilcox, upon the practical side of the question, entitled "Irrigation Farming," in which he says: "In summarizing the manifold advantages that the irrigation blessing has brought to humanity through all the ages of persevering man, and anticipating those benefits that are to be commanded by 'the nations yet to be,' we may conclude that irrigation means better economic conditions; means small farms, orchards, and vineyards; more homes and greater comfort for men of moderate means. It means more intelligence and knowledge applied to farming, more profit from crops, more freight, and more commerce—because special products of higher grade and better

market value will be enhanced. It means association in urban life instead of isolated farms. It means the occupation of small holdings. It means more telephones, telegraphs, good roads, and swift motors; schools in closer proximity; villages on every hand, and such general prosperity as can hardly be dreamed of by those who are not familiar with the results of even the present infancy of irrigation in America." [1]

The civilizing influence of irrigated agriculture upon the American Indian can not be over-estimated. Through the more modern policy of the Government the Indians are given independent allotments of land and are instructed by experts furnished by the Government in the methods of irrigation. By this means many of the Indian tribes of the Western States have entirely passed from their former savage or indolent condition, and have become respected and industrious people, and in time will be granted full citizenship in this Republic.[2]

All of the above enters into the economic features of the subject under discussion. And, for one of the causes for the change in agricultural life, that has come or is rapidly coming to the irrigated regions of the West, too much credit can not be given to the State agricultural colleges, and the experiment stations of the United States Government, both of which are established in every State included within the arid West.

§ 10. Irrigation and storage of waters as a means of solving other important questions.—There is another important group of questions looking toward the economic side of the subject of the irrigation of arid lands, and tending toward the solution of other important problems which confront the country at the present time. These are: The question of forests as related to stream flow, hereinafter more fully discussed in a separate chapter of this work; [1] irrigation as a means of the prevention of floods; [2] as an aid to navigation; [3] as aiding in the reclamation of overflowed or

1 Irrigation Farming: A Handbook for the Proper Application of Water in the Production of Crops, by Lucius M. Wilcox, editor of the *Field and Farm* of Denver, Colorado, edition 1910, p. 21. [The above work is one of the best written upon the practical side of the question.—AUTHOR.]

2 For irrigation by the Indians see Chap. 12, Secs. 271-285.

1 See Chap. 2, Secs. 40-62.

2 See Sec. 11.

3 See Sec. 12.

swamp lands;[4] as a conserver of the soil,[5] and as an aid to the development of power.[6] All of these subjects are largely related to each other, and concerning which a single comprehensive plan should be, and is being attempted to be adopted by the General Government, through its modern policy of the conservation of its natural resources. Concerning these subjects, President Roosevelt wisely said: "It is the part of wisdom not to adopt a jumble of unrelated plans, but a single comprehensive scheme for meeting all the demands so far as possible at the same time and by the same means."[7]

At the Conference of Governors, held in Washington in 1908, Professor Chamberlain, at the head of the department of geology of the University of Chicago, upon this subject said: "The solution of the problem for the tiller of the soil essentially solves the whole train of problems running from farm to river and from crop production to navigation."[8] We will take these subjects up and briefly discuss them in the following sections, with the exception of the relation of forests to stream flow, which requires a more elaborate discussion, which will be found in a subsequent chapter.[9]

§ 11. **Irrigation as the means of preventing floods.**—In a recent bulletin, published by the United States Government, it is stated that the damage from floods in the United States probably exceeds on the average $100,000,000 annually, and in the year 1908, according to estimates based on reliable data, the aggregate damage approximated $250,000,000. "Such an annual tax on the property of great regions should be reduced in the orderly progress of government." It goes without saying that any consideration of flood prevention must be based on the thorough knowledge of stream flow, both in the contributing areas which furnish the water and along the great lowland rivers.[1] The forests are the greatest natural conservers of moisture known to man.[2]

4 See Sec. 14.
5 See Sec. 13.
6 See Sec. 15.
7 From the speech of October 4, 1907, at Memphis, Tenn.
8 Proceedings, p. 80.
9 For the relation of forests to stream flow, see Chap. 2, Secs. 40-62.

1 Surface Water Supply of the Lower Mississippi Basin, by W. B. Freeman and R. H. Bolster, 1911, Water-Supply Paper No. 276, U. S. Geol. Survey.
2 See Chapter, Forests and Their Relation to Stream Flow, Secs. 40-62, and authorities cited.

With their leafy cover, breaking the force of the rain, their porous floor, and friable soil, they absorb the rainfall, and it is thus stored up until it gradually seeps, percolates, or runs by subterranean streams, through the earth into the springs and streams below. By this means a fairly even flow is maintained in the rivers during the entire year. But with the forest at the headwaters gone, no such thing occurs. The rainfall and water from melting snow rushes off the land, fills the streams and rivers to an abnormal height, and thus causes the great floods on the lower lands, which cause so much damage in this country each year.[3]

By practicing irrigation, man is, in a way, an imitator of Nature. This is accomplished in two ways: First, by taking out the flood water directly from the rivers or their tributaries; second, by constructing great artificial reservoirs wherein the flood water is stored for a time. This water in either case is spread out over vast areas of land through a network of ditches on the upper drainage basins of the rivers and used for irrigation, and, after having accomplished its main object in fertilizing crops, gradually infiltrates back into the streams, at the times when the main flood has passed, and thus insures a regular flow in the rivers below. These lands upon which the water is spread absorb it like a sponge and very slowly give it out by the process of seepage and percolation into the tributary streams of the great rivers. By this means floods may be prevented and at the same time insure a larger flow in the rivers during the dry seasons.[4]

3 See Sec. 55, and authorities.

4 See Reclus, The Earth, pp. 328-338; Marsh, The Earth as Modified by Human Action, pp. 448-453; Shaler, Aspects of the Earth, pp. 189, 295; Speech of Francis G. Newlands of Nevada in the Senate of the United States, Vol. 42, Cong. Record, No. 14, p. 500; Vigan, Etudes sur Irrigations, 1867; Scott Moncrieff, Irrigation in Southern Europe, pp. 89, 90.

Speaking of storage reservoirs as a preventive for floods, before the Conference of Governors, held in the White House, Washington, D. C., May 13-15, 1909, Mr. Lyman E. Cooley, C. E., said: "Floods will be abolished or mitigated, thus claiming the wealth in alluvial lands along the water courses and making the valleys salubrious. The flow of streams will be equalized and made navigable throughout the year, even to the remote reservoir sites."—Proceedings of the Conference, p. 350.

At the same conference Mr. Edward Gillette of Wyoming said: "A wonderful work is being performed in the

Practically all of the water withdrawn from the streams and used in irrigation—except that which is absorbed by the vege-

West by conserving flood waters and letting them go back gradually to the streams after having been used on land for irrigation purposes. This work justifies the hearty co-operation of the whole country.''—Proceedings, p. 398.

See, also, the speech of the Chancellor of the Chancery Court, Nashville, Tenn., Proceedings, beginning p. 376; Floods, by M. O. Leighton, Chief Hydrographer, U. S. Geological Survey, embodied in Vol. 2, p. 95, as part of the report of the National Conservation Commission. See, also, same Water-Supply Paper No. 234, U. S. Geol. Survey.

See, also, the following bulletins of the Office of Experiment Stations, U. S. Dept. of Agriculture, relative to the drainage of swamp lands: No. 147, Report on Drainage Investigations, 1903, by C. G. Elliott; No. 189, Report on the Drainage of Certain Counties in North Dakota, by John T. Stewart; No. 198, The Prevention of Injury by Floods in Neosho Valley, Kansas, by J. O. Wright; No. 230, Report on the St. Francis Valley Drainage Project in Northeastern Arkansas, by A. E. Morgan and O. G. Baxter; No. 234, A Report upon the Reclamation of the Overflowed Lands in the Marais des Cygnes Valley, Kansas, by S. H. McCrory and D. L. Yarnell.

Also, see the following circulars of the same Department: No. 74, Excavating Machinery Used for Digging Ditches and Building Levees, by J. O. Wright; No. 76, The Swamp and Overflowed Lands of the United States, by J. O. Wright; No. 80, A Report upon the Drainage of the Agriculture Lands in the Kankakee River Valley, Indiana, by C. G. Elliott; No. 81, A Report upon the Drainage of the Agricultural Lands of Bolivar County, Mississippi, by W. J. McEathron and S. H. McCrory; No. 86, Preliminary Report upon the St. Francis Drainage Project in Northeastern Arkansas, by A. E. Morgan; No. 103, The Drainage Situation in the Lower Rio Grande Valley, Texas, by L. L. Hidinger; No. 104, Preliminary Report on the Drainage of the Fifth Louisiana Levee District, by A. E. Morgan, S. H. McCrory, and L. L. Hidinger.

See, also, the following documents issued as ''Separates'' by the Agricultural Department: No. 845, Report of Drainage Investigations, 1904, by C. G. Elliott, same in Office of Exp. Stas. Bul. No. 158, Separate No. 9; No. 925, Drainage Investigations, by C. G. Elliott, same in Annual Report of the Office of Exp. Stas. for 1905; No. 1028, Reclamation of Tide Lands, by J. O. Wright, same in Annual Report of the Office Exp. Stas. for 1906; No. 1136 Progress in Drainage, by C. G. Elliott, same in Annual Report of the Office of Exp. Stas. for 1907; No. 1222, The Alluvial Lands of the Lower Mississippi Valley and Their Drainage, same in Annual Report of the Office of Exp. Stas. for 1908; No. 1315, Reclamation of Southern Louisiana Wet Prairie Lands, by A. D. Morehouse, same in Annual Report of the Office of Exp. Stas. for 1909; No. 1386, Drainage Investigations, 1909-1910, by R. D. Marsden, same in Annual Report of the Office Exp. Stas. for 1910.

Also, see the following miscellaneous documents issued by the same Department: Sen. Doc. 443, 60th Cong., 1st Ses., Swamp Lands of the United States; House Doc. 1180, 61st Cong.,

tation, and that which is carried off by evaporation—is finally restored to the river below either by superficial flow or infiltration.[5] This restoration is not immediate, and it may take more than one season or even years for the water to find its way into the river below, but it eventually gets there. Hence a stream on the upper headwaters of a river may be entirely diverted and applied to irrigation during the summer months; this would have almost an immediate effect to lower the flow in the river, at least until the seepage began to get through. Therefore the diversion of water during any other period of the year than that of flood water might be an almost immediate injury to the industries on the river below depending upon the water supply in the river. Upon the other hand, the diversion and storage of the waters of a river, or its tributaries, during the high water or flood season, has exactly the reverse effect. It tends to prevent the floods in the lower reaches of the river at times of high water; and, afterwards, lets it down during the period of low water, and thereby maintains a more equable flow in the river.[6]

§ 12. Irrigation as an aid to navigation.—Not only can irrigation be made a means of preventing floods, but it may also be made a great aid to the inland navigation, or navigation of the rivers and lakes of this country. As has been seen in the previous section, and will be seen in our discussion upon forests and their relation to stream flow,[1] that unless the water of a drainage basin is stored either by Nature through its forests, or by man in an artificial way, that the greater portion of the water from

3d Ses., Expenditures for Drainage Investigations; Bul. 3-B, Preliminary Report upon the Drainage of the Lands Overflowed by the Forked Deer and the Obion River in Gibson County, Tenn., by E. A. Morgan and H. S. McCrory; Bul. 25, A Preliminary Report on Drainage Reclamation in Georgia; Bul. 110, Installation of an Experiment Drainage System, by John T. Stewart (for this address Supt. Northwest Experiment Farm, St. Paul, Minn.); Report of the Iowa State Drainage Waterways and Conservation Commission, 1910 (for this address Secy. of State, Des Moines, Iowa).

See, also, House Document No. 1180 for a classified list by States of surveys conducted by drainage investigations, giving the approximate number of acres benefited and the amounts expended.

5 Marsh, The Earth as Modified by Human Action, pp. 450, 451.

6 See, also, Irrigation as an Aid to Navigation, Sec. 12.

1 See Secs. 40-62, and authorities cited.

the rainfall, or from melting snows, runs off almost immediately. When this is the case, it follows as a natural consequence, that during the dry seasons of the year, the rivers below are much lower, than they were formerly, when the upper drainage basins were forested; and at times they get so low that some of our rivers formerly important for navigation can not be used for that purpose at all.

Professor Shaler, of Harvard University, one of the greatest authorities upon this subject, says: "With the removal of the forests, the winter floods increase in magnitude, and the summer droughts leave so little water in the streams that they are constantly becoming less serviceable for navigation."[2] In fact the inland navigation of this country has been so injured from this cause that it has been called to the attention of the people and Congress in a number of messages of our presidents, and also Congress has taken the subject up in the matter of the Inland Waterway Commission Bill.[3]

By irrigation the flood water is stored for a time, either in reservoirs constructed for this purpose, or in the soil itself, or both.

2 Shaler, Aspects of the Earth, 1890, p. 293.

3 For text of bill, see Vol. 42, Cong. Record, No. 14, p. 497; and for discussion upon bill by Senator Newlands of Nevada, see *id.*, pp. 497-513.

The Inland Waterways Commission was appointed by President Roosevelt in 1907, and was the outgrowth of the agitation which had been conducted for some time prior thereto, particularly in the Mississippi Valley, for the improvement of our waterways. The President had been appealed to to recommend legislation to Congress on this subject, and, with his usual thoroughness in such matters, had determined to exhaust investigation before making his recommendations. He therefore appointed this Commission, composed of men who, either in legislative or in administrative work, had enjoyed exceptional opportunities of studying the problems relating to the waterways of the country. The President selected as chairman of the Commission the Hon. Theodore Burton of Ohio, who had for years been the chairman of the Rivers and Harbors Committee of the House. The additional members of the Commission were Mr. John H. Bankhead of Alabama, the leading minority member of the Rivers and Harbors Committee of the House, but now United States Senator from Alabama; Senator Warner of Missouri, and Senator Newlands of Nevada. The administrative and scientific members of the Commission were General Mackenzie, chief of the Engineer Corps of the Army; Dr. McGee, a noted scientist and naturalist; Mr. Newell, chief of the Reclamation Service; Mr. Pinchot, chief of the Bureau of Forestry; Mr. Smith, chief of the Bureau of Corporations. The primary purpose of this inquiry is to facilitate water transportation,

This water slowly infiltrating or being let down in the time of the summer droughts finds its way to the lower rivers, and, in a degree, compensates for the deficiency in the flow of those rivers during that season, caused by the destruction of the forests. By this means the rivers that were navigable in the early history of our country may have their summer flow restored. As Senator Newlands said in his speech in the Senate of the United States upon the Inland Waterway Commission Bill, speaking about storing the flood water: "These plains absorb the water like a sponge and gradually give it out by process of seepage to the tributary streams of the great river. Give it out when? Give it out when it is most needed for navigation, during the months of July, August, and September. So irrigation is the proper method of treating the river for navigation, for it is one method of impounding the flood waters of these tributary streams; preventing those flood waters from creating destruction below in the spring and preserving them for a beneficent purpose later on in the summer and fall months."[4] In the Conference of Governors called by President Roosevelt in 1908, Mr. Andrew Carnegie said: "In conclusion, Mr. President and Governors of our States, it seems to me our duty is: First, conservation of forests, for no forests, no long navigable rivers; no rivers, no cheap transportation. Second, to systematize our water transportation, putting the whole work in the hands of the Reclamation Service, which has already proved itself highly capable by its admirable work."[5]

Mr. Lyman E. Cooley, C. E., in speaking of the value of the storage of waters for this purpose, said: "The flow of streams will be equalized and made navigable throughout the year, even to the remote reservoir sites, and by improvement of these channels and by connecting the water systems at vantage points, a great transportation agency will be evolved as a complement to our railway

upon which the prosperity of the country so much depends. The reports of this committee were made to Congress from time to time, and are now available.

[4] Vol. 42, Cong. Record, No. 14, p. 500. See Secs. 54, 55.

See, also, Shaler, Aspects of the Earth, pp. 293-295; Fernow, Economics of Forestry, 1902, pp. 74, 75; Marsh, The Earth as Modified by Human Action, p. 451.

[5] Proceedings of Conference of Governors, 1908, p. 24.

system, and as a necessity for our larger growth and complete development."[6]

§ 13. **Irrigation as a conserver of soil.**—It was said by President Roosevelt in his Memphis speech: "It is computed that one-fifth of a cubic mile in volume, or one billion tons in weight of the richest soil matter of the United States, is annually gathered in storm rivulets, washed into rivers, and borne into the sea. The loss to the farmer is in effect a tax greater than all other land taxes combined, and one yielding absolutely no return."[1]

The annual loss to the people of the United States through soil wash is far greater than can be easily conceived. The stripping away of the forests has left the soil, in many parts of the country, a prey to torrential floods. This soil, by being washed away, not only leaves the country from whence it came

[6] Proceedings Conference of Governors, p. 350.

See, also, Transportation by Water, by Herbert Knox Smith, Commissioner of Corporations, Vol. 2, pp. 13-58, Report of the National Conservation Commission.

[1] 2 The Roosevelt Policy, p. 624.

See, also, Washed Soils, Farmers' Bulletin No. 20, U. S. Dept. of Agri.; A special contribution to Soil Erosion, prepared for the Secretary of the Interior, by W. J. McGee; The Beginning of Agriculture, by W. J. McGee; Rock, Weathering and Soils, by Dr. Geo. P. Merrill of the National Museum; Soils, by Professor F. H. King; Soil Physics, Soil Management and Soils, by Professor E. W. Hilgard; Exhaustion and Abandonment of Soils, Testimony of Milton Whitney, chief of the Division of Soils, before the Industrial Commission, 1901, U. S. Dept. Agriculture, Report No. 70; Soil Fertility, by Milton Whitney, Farmers' Bulletin No. 257, U. S. Dept. Agriculture; The Chemistry of the Soil as Related to Crop Production, by Milton Whitney and F. K. Cameron, Bulletin No. 22, Bureau of Soils, U. S. Dept. Agriculture.

See, also, the chapter herein on forests as related to stream flow, Chap. 2, Secs. 40-62, and authorities there cited; Address on Soil Wastage, by T. C. Chamberlain, head of the Dept. of Geology of the University of Chicago, at the Conference of Governors, Washington, 1908, Proceedings, p. 75; Address of R. C. Van Hise, President National Association of State Universities, at the same conference, Proceedings, p. 426.

See, also, address of President Taft at Kansas City, Mo., Sept. 25, 1911, Office of the Secretary, Circular No. 38, U. S. Dept. Agriculture.

See, also, article on Denudation, by R. H. Dole and H. Stabler of the water resource branch, U. S. Geological Survey, Vol. 2. pp. 126-140, Report of the National Conservation Commission; same in Water-Supply Paper No. 234, p. 78.

bare, in many places even down to the solid rock, but also the soil itself with great masses of sand and rock is carried down the streams and rivers and is a great source of damage where it lodges. It often destroys navigation; it also raises the beds of streams and causes them to overflow the low lands, and often causes them to permanently change their courses, thereby destroying vast amounts of valuable property. And, not only this, but the good lands even along the upper reaches of the river system are covered up by the debris and rendered practically worthless.[2]

A comprehensive scheme of irrigation systems in this country will do much toward the conservation of our soils. By the storage of the waters in times of flood or high water, the floods themselves will, in a measure, be averted. Such systems, when properly administered, operate to extend the alluvial belt of the rivers and streams by taking the water from them charged with silt and sediment and distributing it over the surface of the lands in such a manner that the silt is retained in the soil where it is first deposited. It thereby becomes a benefit instead of an injury, as is the case where this silt is carried down to the lower reaches of the rivers. The systems of banks, ditches, and ridges, which have to be constructed on irrigated fields, also tend greatly to prevent the violent washing away of the soil in times of flood.

§ 14. Irrigation as aiding in the reclamation of swamp lands.—More than 70,000,000 acres of the richest land in this country are now practically worthless or of slight value by reason of overflow and swamp conditions. When this land is drained it becomes exceedingly productive and its value increases many fold. It is claimed that by the reclamation of these lands at least $700,000,000 would be added to our national resources. The study of the run-off is one of the first subjects to consider in connection with the drainage projects of any of these lands. If by the drainage of a large area of swamp land into any particular channel, that channel becomes so gorged with water, which it had not hitherto been called upon to convey, the water is bound to break out and flood other lands below where previously it was not subject to inundation. In such a case, it results merely in an exchange of land values, and, probably great damage to the

2 See Forests as Related to Stream Flow, Chap. 2, Secs. 40-62.

owners of the newly flooded lands. I do not understand that this is the object of drainage improvement.

Upon the other hand, the holding back a considerable portion of the flood water of our great river systems in great reservoirs for the purpose of irrigation is already having the effect in aiding in the reclamation of swamp lands along their lower reaches. And, as greater storage works are constructed and utilized, this result will become greater and greater; and, at the same time, the water held up may be used for irrigation of arid lands, and for power purposes. It can be readily seen that, if the water of a river system is held up, and a considerable portion of the same is not permitted to flow down during the periods of high or flood water, the low lands adjacent to the lower portions of the river are not as liable to be newly flooded, and at the same time the main channel of the river will be kept open for the drainage of these low lands.[1] This as well as the other subjects discussed in this portion of this chapter comes within the suggestion of President Roosevelt in his Memphis speech for a single and comprehensive scheme for meeting all demands as far as possible.[2]

§ 15. Irrigation as an aid in the development of power.—As our coal and timber lands are becoming depleted, it is becoming a serious question as to from what source we are to obtain power, heat, and light. Nor are our apprehensions entirely for future generations, but the effect of the increased demands and the scarcity of the supply of coal and wood are now felt by the present generation as is manifest by the greatly increased prices of these products. And in this respect, the development of the water power of the country has become a National economic necessity. "Industrial growth, and as a consequence the progress of the United States as a nation will cease if cheap power is not available."[1] Water supply affords the only known source now open

1 See Surface Water Supply of the Lower Mississippi Basin, by W. B. Freeman and R. H. Bolster, Water-Supply Paper No. 276.

See, also, for a kindred subject, Tidal Marshes and Their Reclamation, by George M. Warren, 1911, Bulletin No. 240, Office of Experiment Stations, U. S. Department of Agriculture.

2 2 The Roosevelt Policy, p. 625.

1 Surface Water Supply of the Lower Mississippi, by W. B. Freeman and R. H. Bolster, Water Supply Paper No. 276.

to supply this deficiency. And when the electric transmission of power was accomplished the relation of our water powers to National economy was entirely changed. [2]

As stated by M. O. Leighton, Chief Hydrographer of the United States Geological Survey, and embodied as a part of the National Conservation Commission: "The construction of reservoirs necessary to prevent floods, would, under proper management, involve an increase in the water-power possibilities of the United States equal to about 60,000,000 horse-power." [3] In this country, during recent years, the development of electrical energy, for the purpose of transmitting the same to distant parts for use, in connection with irrigation projects, is becoming a common industry. This is especially true of the Reclamation Service working under the National Reclamation Act, but it is also true of private, State, and municipal projects. Neither enterprise is injured by the other in the slightest degree, and both can be worked together; and, furthermore, it is only by this means that the water can be made to do duty to its fullest possible capacity.

§ 16. The theory of irrigation.—The fact that water artificially applied to lands produces crops upon some portions which were absolutely barren without it, and increases the yield upon others, may be attributed to the following causes: First, as the temperature of the water is rarely below ten degrees Fahr. above freezing, it prevents the frosts in winter from injuring the plants by heaving the soil, raising the roots to the surface and freezing them; the growth, especially of the roots, is encouraged. Second, nourishment is brought to the soil in the shape of sediment and mineral substances carried in solution which are of the nature of plant food, and which are absorbed and retained both for imme-

[2] See the Public Utility of Water Powers and their Governmental Regulation, by Rene Tavernier, Chief Engineer of the public works of the Republic of France, and Marshall O. Leighton, Chief Hydrographer, U. S. Geol. Survey, 1910, Water-Supply Paper No. 238.

See, also, for the development of power and power rights, Chap. 47, Secs. 847-855.

[3] Vol. 2, p. 111, Report National Conservation Commission; for the same, see Water-Supply Paper No. 234, p. 27.

See, also, for the report upon Developed Water Powers, Vol. 2, p. 141, same Report; and also Water-Supply Paper No. 234, p. 28; and on Undeveloped Water Powers, Vol. 2, p. 159, same Report; and also Water-Supply Paper No. 234, p. 46.

diate and future use. Third, the plant food already present in the soil itself is by the action of the water brought in contact with the roots of the plants; and lastly, the retention in the soil of the various plant foods prevents it being worn out at the end of a few seasons, and constantly improves it. To the united agency of the above named causes may safely be attributed the benefits that arise from irrigation. It also appears that there is a great benefit derived from the mere contact of abundance of moving water of an even temperature with the roots of the various plants. Why can not crops be grown without irrigation, in a dry desert country? It is simply because the amount of moisture evaporated from the surface of leaves and stems in our commonly cultivated food plants is so much greater in an arid climate than the amount which is naturally furnished to their roots to absorb that the plant dries up and dies. There are many species of native plants in our most arid lands,[1] but their tissues are so constituted that the process of evaporation, or transpiration,[2] as it is called in vegetable physiology, is exceedingly restricted, and therefore additional moisture is not needed to promote their growth, even under conditions of great drought, when transpiration is most rapid. Upon the other hand, nearly all of our food plants have originated in, and are natives of humid climates, and are therefore incompetent to cope with the hot, dry soil and atmosphere of an arid climate, without an additional supply of moisture being artificially furnished. The most perfect and the most natural key to the natural agricultural capacity of any region, outside of a chemical analysis of the soil, is the character of its original vegetation. In plants of an arid region, the thick cuticle, the covering of felted hairs, the reduced leaf surface, as well as the size of the plants themselves, and the almost sombre grey colors are some of the evidences of aridity. In the humid regions, the plants are larger, they have broad, thin leaves and a bright green color, and an absence of the protective hairy blanket, which are all evident signs of adaptation to different conditions of humidity. But where the native plants grow with the supply of moisture, which Nature alone furnishes, it is ar-

1 We are considering arid arable lands and not actual desert lands. For the distinction between arid lands and desert lands, see Sec. 3.

2 For transpiration, see Sec. 28.

gued, and correctly, that the food plants, which can be grown in that particular climate, can be grown upon these lands, with the additional moisture, necessary for their existence and successful production, artificially supplied by irrigation. The physiological effect of irrigation is then to furnish, for absorption by the roots of the plants, sufficient moisture to balance the excessive amount transpired from their leaves.

§ 17. **Special benefits from irrigation.**—In what manner, then, does water applied by irrigation operate in fertilizing barren soils, and increasing their product? Besides supplying the deficiency in moisture to the roots of the plants, as an element itself it furnishes direct supplies of food which are partly required for plant life. As a medium for moderating the temperature of the climate, it lessens the rigors of the intense cold in some regions, and of intense heat in others. As a destroyer of noxious weeds and of insects, it often entirely extirpates these when under proper direction. As a means of conveying fertilizing and enriching substances to the soil, and therefore adding to the necessary plant food, it may be used with great success. In an irrigated country "worn out" soils, so common to the New England States, are almost unknown. In the various modes of operation there occur numerous features, varying with the localities and their surroundings, and all these must be well considered in order to secure most of those beneficial effects which water is qualified to promote by means of irrigation. It follows, therefore, that great attention ought to be given to the qualities of water intended for the purpose; and that before incurring great labor or expense in the application of it these qualities ought first to be known. This may be done partly by analysis, but most certainly by experiments conducted on a moderate scale, until it is fully determined just what is best under all circumstances of the case. In general, spring waters are very fertilizing and possess an equable temperature, but impregnations of iron and some other minerals are quite frequent, especially in mountainous districts, even in springs, and should be avoided; mountainous streams which hold lime in solution are very fertilizing; such streams as convey enriching sediment and silt are the best and most effectual for permanent improvement of the soil.

The natural produce for which irrigation is best adapted, in particular soils and climates, comes next under consideration. Here the mere operator is not always a competent judge, and it may require careful observation and analysis of the soil and, perhaps, actual experiments, to ascertain the facts.[1] But there is no doubt that they may be ascertained with a considerable degree of certainty before a great deal of expense has been incurred.

The questions of the character of the soil and water, and the crops which a combination of the two will nourish and produce most successfully, being settled in the first place, the operator must then consider the population and the markets of the district for his products, his own demands, and the amount of competition that he may have. All these questions must be carefully considered in his determination of the nature and extent of the irrigated crops which he will plant or sow, and from which he may expect to derive the most profit.

§ 18. To what crops irrigation is best adapted.—In the selection of the crops which the irrigator is about to plant or sow, first and foremost, due regard must be had of the climate where the opera-

[1] For the relation of soils to irrigation, see Irrigation Farming, by Lucius M. Wilcox, 1910, Chap. 111, pp. 22-35; Primer of Irrigation, Anderson, 1905, pp. 54-66.

See, also, the various bulletins issued by the U. S. Department of Agriculture, Bureau of Soils.

For several years the United States Interior Department has conducted the United States Geological Survey and has issued what is known as "Water Supply and Irrigation Papers." Also the United States Department of Agriculture has issued two sets of bulletins known as "Irrigation and Drainage Investigations," and "Farmers' Bulletins." These bulletins are written by most eminent men and treat the subject from every phase of the scientific standpoint. The most of these bulletins are accessible and can be obtained from the respective Departments of the Government.

For the practical irrigator, The Primer of Irrigation, by D. H. Anderson, editor of *The Irrigation Age*, Chicago, 1905, will be found a most valuable work; and also the current numbers of *The Irrigation Age*, where these questions are discussed at length.

See, also, Irrigating the Farm, by L. M. Wilcox, Denver, the editor of the *Field and Farm*, and also the current numbers of that periodical; also see Irrigation Farming, same author, 1910; also, Irrigation for Farm and Garden, Stewart; Irrigation and Drainage, by F. H. King; Irrigation in the United States, by F. H. Newell, Director of the National Reclamation Service.

tions are about to be carried on. It would be a vain undertaking to attempt to raise, for a profit, oranges in North Dakota or cotton in Montana. But, barring the climatic consideration, any crop can be grown by irrigation that can be grown without it, and with a much greater yield, and usually of a better quality.[1]

There is an impression among some, especially in the Eastern States, that irrigation can be successfully applied only to certain branches of agriculture; that horticulture is the industry especially benefited by it, and that as to any other crop it does not much better the condition, financially or otherwise. It is true that fruit culture will usually give larger returns per acre under irrigation than most other branches; but it is also true that it does this under ordinary conditions. The desirable results of a more certain crop and a larger yield are just as certainly secured with wheat, corn, alfalfa, and potatoes as with oranges, lemons, and apples. Sugar beets are easily raised at what would be called an enormous profit to the Eastern farmer; and great dividend paying corporations for the manufacture of sugar have sprung up in many portions of the arid West.[2] Stock and horse raising are also much benefited by irrigation, as the pastures may always be kept green and fresh, and great crops of hay and fodder may be produced. Alfalfa, or lucerne, the great forage crop of the arid regions of the United Sates, is made to yield from two to five crops a year, which aggregate a tonnage it would be impossible to secure from any meadow under ordinary conditions in the Eastern States, and which in value will closely rival a productive fruit orchard. Grain crops and potatoes may likewise be increased, and almost every product known to agriculture will not only yield more, by this method, but will also give a greater return above the cost of production. Especially valuable is irrigation in the raising of vegetables, melons, and garden produce. Near the cities and towns of the arid region, the market gardeners, upon a patch of ground of from one to five acres, properly irrigated, can raise an amount of garden truck that surprises the market gardeners of the Eastern States, who depend entirely upon the rain-

1 For the particular features of each State in the arid region, see Part 14.

2 Progress of the Beet-Sugar Industry in the United States, 1904, by Chas. F. Saylor, Special Agent; Primer of Irrigation, Anderson, 1905, Chaps. 7, 20, 22, pp. 218-245.

fall. The Eastern gardener requires a much greater area of land to produce the same amount of crops than is required in the West under irrigation. It is for this reason that the National Reclamation Service, under some of the projects constructed by the Government, has fixed the farm unit as low as ten acres; this amount of land being deemed sufficient for a man to well support himself and family.[3]

One of the greatest proofs of the value of irrigation lies in the fact that no farmer, who has once practiced it, is willing to return to the pursuit of agriculture in any part of the country where he would be entirely dependent upon the uncertain rainfall.

§ 19. **The effect of irrigation upon the climate.**—The effect that irrigation has upon the climate of a certain designated section of a country requires a careful study of the physical conditions of the given locality. It also requires a comparison of the meteorological data for a considerable period of time while the arid conditions prevailed, with similar data after the same territory has been brought under irrigation. Owing to the fact that this data is not always obtainable, especially before the section was irrigated, just what effect irrigation in a naturally arid region has upon the climate of that particular region is an inherently difficult problem under the most favorable conditions, and the research for the solution of the same must cover a considerable period of time. Captain William A. Glassford of the United States Signal Corps, and a high authority upon this subject, writing in regard to the climate of Arizona, says: "In the hottest parts of this arid region the midsummer weather is not only endurable, but even enjoyable and refreshing. These are facts as they exist now, when the present conditions—the bare soil, etc.—are specially conducive to high temperatures. But it may be readily conceived that there will take place salubrious modifications, as some of us have already realized, when these desert places are covered with the green carpet of alfalfa and the verdure of trees."

From investigations made by the United States and by various scientists it has been found that irrigation has a slight influence in increasing the moisture in the surrounding air, for the follow-

[3] For the National Reclamation Act, see Chap. 65. See, also, the annual reports of the Reclamation Service.

ing reasons: That the moisture is evaporated as an invisible gas; that the greater portion instantly rises with great velocity to a point in the atmosphere where the temperature is below dew point, where it becomes visible in the form of clouds, but which are usually driven from over the place from which the moisture first arose by the prevailing wind. But a very small portion of the evaporated moisture is retained in the lower and warmer strata of the air. It is generally considered that the effect of the moisture which is drawn off from irrigated fields slightly tends toward increasing the humidity of the atmosphere of the particular section from which it was drawn. But as far as temperature is concerned, irrigation cools the atmosphere for the reason that the hotter the air the greater is the evaporation from the irrigated ground. This evaporation lowers the temperature of the region where the irrigation is practiced and of the surrounding air. Although the condensation of the vapor may not take place within days of time and many miles distance from the place where it was exhaled from the surface, a local refrigeration must accompany a local evaporation. Hence, although the summer temperature of an irrigated region may be high, we are warranted in affirming that it must have been still higher before the introduction of irrigation, and would again become so if that practice was discontinued.[1]

§ 20. **The effect of irrigation upon the rainfall.**—The only effect that irrigation can have upon the rainfall, is upon what is called the secondary rainfall; that is to say from the moisture that is evaporated from an irrigated area and returned in the form of showers to that locality. The fact that there is a very considerable precipitation in those localities in the summer months, where irrigation is now practiced, and where prior to its practice the summer rainfall was very small, is a strong argument in its favor. The atmosphere of a locality, especially where the climate is very hot, is naturally exceedingly dry during the period of irrigation, but it receives immense quantities of moisture from the irrigated soil, and from the plants, which, if not driven elsewhere by the wind, are condensed by the colder strata of the air into what is called secondary rainfall. The greater the area irrigated,

1 Marsh, The Earth as Modified by Human Action, p. 449.

See, also, the chapter on forests as related to stream flow, Secs. 44-46.

the greater this is noticed. This is so from the fact that the clouds, moisture ladened from the irrigated lands, are oftentimes caught up by the winds and carried to other regions where they may precipitate their moisture. It often occurs that these clouds in floating through the air encounter mountain ranges, adjacent to the valleys from which the moisture was drawn, and there precipitate their moisture. This is the cause of many of the local showers in the mountains, although it may not rain in the adjacent valley. These showers sometimes add to the water supply of the same drainage basin, during the summer periods, when the water is needed the most, for irrigation in the valley.[1] Professor Shaler, in speaking of the loss of the forests causing a loss of the secondary rainfall, says that the rapid extension of irrigation, which is sure to take place in the more arid sections of this country, will afford a similar, and, perhaps in time, an equal supply of moisture for these secondary rains.[2]

§ 21. The effect of irrigation upon health.—A discussion of the effect that irrigation has upon the health of the inhabitants of a community, where the land is cultivated by that method, requires a study of the physical and meteorological data both before and after the land was so cultivated. It also requires a study of the percentage of humidity most conducive to health, with the prevailing temperatures, altitude, and the movements of the wind, and the determination of actual and ascertained general effects, as shown by the freedom from disease, or the contrary, in the community, and by vital statistics. Also, each of these elements of the problem must be studied in its relation to each and all of the others.

It is universally conceded that an atmosphere carrying too much moisture is unfavorable to perfect health. It is equally certain that the air may be too dry. In an arid country, without irrigation, the moisture in the atmosphere is sometimes so little as to interfere with health and comfort, and produce feverish conditions. The evaporation of water from irrigated lands supplies

1 See the chapter on forests as related to stream flow, Sec. 47, and authorities cited.

See, also, Marsh, The Earth as Modified by Human Action, 1884, pp. 448, 449.

2 Shaler, Aspects of the Earth, 1890, p. 295; see, also, pp. 273, 274.

this deficiency to the air and obviates the injurious tendencies. It is well known that a well-shaded dwelling in the midst of an alfalfa field is much cooler than the same residence surrounded by bare ground. This is due in part, perhaps, to the absence of reflection from the earth, but chiefly, I think, to a similar slight refrigeration of the air by evaporation of the moisture in the earth and vegetation of the surrounding field. The effect becomes still more marked when a gentle breeze is blowing. In an arid country, during the summer months, the air is so dry that the midday registration of relative humidity ranges from six to fifteen per cent. It rarely goes above the latter point, and in sections of the same part of the country, where irrigation is not practiced, it drops still lower, which is not desirable to general healthfulness. The conclusions from this point to the fact that the evaporation of moisture from irrigated surfaces slightly increases the moisture in the air and promotes the healthfulness of both animal and plant life. The above rule applies, however, only to arid countries. There is one very noted exception, and that is where irrigation is applied to the cultivation of rice in the Southern States and in other countries. In these localities irrigation has been proven to be a positive injury to the healthfulness, especially for the white man.[1]

§ 22. **The effect of irrigation on summer frosts.**—The question of the effect which irrigation has in increasing or decreasing the summer frosts which occur in certain portions of the arid and semi-arid regions is one of deep interest to the residents of these districts. At first glance it would seem that the wetting of any considerable areas of land would have the effect of cooling the atmosphere and increasing the probability of frost, for it is within the experience of many that low, wet, or marshy lands are very much more subject to frost than the high and dry bench lands. However, the data obtainable regarding the experience of certain

1 See Marsh, The Earth as Modified by Human Action, pp. 452, 453; Escourrou-Milliago, L'Italie a propos de L'Exposition de Paris, 1856, p. 92. But see Carlo Livi, Della coltivazione del Piso in Italian, in the Nuova Antologia for July, 1871, p. 599.

According to Florence Nightingale, in India, fever rarely occurs in a village surrounded by rice swamps, as long as the water is moving—living, as the natives say. The fever begins when the water falls and stagnates.—Life and Death in India.

of the States and Territories in this country upon this subject leaves no room for doubt that the application of water through irrigation has quite a contrary effect to that mentioned, and that the recurrence of summer frost has been diminished thereby. This has also been the experience in Canada, where summer frosts are quite common, and it has been proven to be a fact that in certain of the irrigated areas in the central and northern portions, much disappointment and loss was experienced in the early days of irrigation owing to summer frosts, and that in these same districts the recurrence of frosts is becoming much more rare, and crops are now successfully raised, which, owing to their susceptibility to frost, would not have been attempted by the most sanguine many years ago. It will be also of interest to note that in Southern Alberta, Canada, it has been the experience that irrigated crops were untouched by frosts, while adjoining unirrigated portions were destroyed; this was true in the case of vegetables as well as grain.[1]

From a careful consideration of the facts obtainable upon this subject it may be safely assumed that among the beneficial results, which will accrue to our arid and semi-arid regions from irrigation, not the least important will be the favorable influence which it will have in diminishing summer frosts.

§ 23. The natural distribution of water diverted for irrigation.—There would seem to be no end of tolls on the water diverted from its natural source for irrigation before it reaches the plants it is intended to nourish. To such an extent is this true that the amount actually utilized by the vegetation frequently bears but a small percentage to the volume diverted. Some loss is necessary under every known condition; but the amount of the loss varies greatly according to the varying conditions and character of the soil, the nature and character of the diverting and conducting works, and preparation of the land where the water is to be applied. For example, for every cubic foot of water per second which passes through the headgate, 30 per cent of the same is liable to be lost in seepage or leakage from the ditch or canal before the field is reached. Then in applying the remamining 70 per cent, if the surface of the land is uneven, a large portion will

1 Irrigation in the Northwest Territories, 1902, p. 65.

flow into the low places and be partially wasted, while the higher places may remain dry. In this way probably not more than 50 out of the 70 per cent reaches the land in such a manner that the plants growing thereon are actually benefited.[1] Now having moistened the soil with these fifty inches, the chances are that at least twenty inches will pass off into the air by evaporation without benefiting in the least degree the plants which it was intended to nourish. Thus of the one hundred inches only thirty may fulfill a useful purpose, and pass through the tissues of the plants and be transformed, or transpired, into vapor at the leaves, and a very small portion used by the crop and stored in the tissues of the plants or its fruit. These subjects of seepage, evaporation, and transpiration will be discussed, in a most general way, in the following sections.[2]

§ 24. Seepage water—Definitions and description.—The water contained in the open spaces occurring in clay, sand, gravel, and

1 For the economic use and the suppression of waste, see Chap. 49, Secs. 847-916.

For the duty of water, see Secs. 902-908.

See article on Water Circulation and Its Control, by Bailey Willis of the U. S. Geological Survey, Vol. 2, pp. 687-710, Report of the National Conservation Commission, 1909; Losses of Irrigation Water and Their Prevention, by R. P. Teele, Annual Report of the Office of Experiment Stations for the year ending June 30, 1907, U. S. Dept. of Agriculture, pp. 369-386.

2 The subjects of leakage losses, and the loss of water by faulty and crude methods of distribution, by unskillful application, and by negligence in not properly preparing the land to receive the water, and by surface runoff, will be discussed under the subjects of Wasting Water, Secs. 911-916, and Duty of Water, Secs. 902-908.

Upon the subject of the proper construction of ditches, canals, and other irrigation works, see Irrigation in the United States, by F. H. Newell, Chief of the Reclamation Service of the United States; Irrigation Engineering, by Herbert M. Wilson; Irrigation and Drainage, by F. H. King.

Upon the subject of the proper preparation of the land for irrigation, see The Primer of Irrigation, by D. H. Anderson, editor of *The Irrigation Age*, Chicago; Irrigation for the Farm, by L. M. Wilcox, editor of the *Field and Farm*, Denver; Irrigation for the Farm and Garden, Stewart. The above works can all be procured from the D. H. Anderson Publishing Co., 30 North Dearborn Street, Chicago, Ill.

See, also, the many bulletins published by the United States Government by the Departments of Agriculture and the U. S. Geological Survey.

See, also, the biennial reports of the various State engineers of the Western States, and the many bulletins issued by the various agricultural colleges of these States.

other materials of which soils and subsoils are composed, is known by various names, such as "soil moisture," "ground water," "ground storage," "subsurface supply," and the like. When this ground water moves down an inclined stratum of porous materials, the term "seepage water" seems to be more appropriate than that of "ground flow," which many writers have recently used. "Seepage water" conveys the idea of lateral motion, but when one uses the terms "soil moisture," "ground water," or "underground water," this conception is usually not implied.[1]

The term "seepage water" is used by irrigators to designate the water which reaches the lowest grounds or the stream channels, swelling the latter by imperceptible degrees and keeping up the flow long after rains have ceased and the snow melted. The word "seepage" is applied particularly to the water which appears in spots below irrigation canals and cultivated fields, usually some months and even years after irrigation has been introduced, and which tends to convert the lowlands into marshes and gives rise to springs, which in turn may be employed in watering other fields. The importance of a thorough knowledge of the behavior of seepage water is obvious when consideration is given to the close relationship which exists between the available water supply and the material prosperity of an arid region where irrigation is practiced. This is particularly true in those regions, where every available source of supply has long since been utilized and where the rapidly increasing agricultural population necessitates the complete utilization of all water obtainable, and that too without unnecessary waste. In countries where irrigation is practiced, it is often the case that, though the streams may be drained dry by the diversion of water into irrigation canals, not far below the stream will again be of considerable size, and this without the flow of visible tributaries. This has become a question of great importance, both economic and legal. And the acquisition of the right to use seepage waters requires the most careful measurements of the streams. The increase which is found in the rivers is attributed to the inflow from springs fed and supplied by the water

[1] Water-Supply and Irrigation Papers No. 7, 1897, by Samuel Fortier, p. 13.

See, also, for subject of ground waters, article by Bailey Willis of the U. S. Geological Survey, Vol. 2, pp. 689, 690, Report National Conservation Commission, 1909.

which has been applied in irrigation upon higher lands. As has been seen, in irrigation, more water is applied than the crop actually uses. A certain amount of the water passes down into the ground and disappears. This varies in amount in different localities and depends upon various conditions. Concurrent observations show that this seepage water usually passes directly downwards, with little or no lateral movement except capillary imbibition, until reaching an impervious stratum, when, filling the interstices, it gradually rises in the subsoil, and passes laterally with a slow movement due to the slope of the water surface which is thus formed. When the passage takes place through the interstices of the soil the movement is very slow. It is faster as the material is coarser. Where there are perceptible channels, the movement may be relatively rapid. [2]

How to lessen unnecessary seepage has been the serious study of those interested in the problem for many years. And in some of the older irrigated sections the question of drainage of the lower lands, affected by the seepage of water applied for the irrigation of lands above, has become as important a question as is the application of the water for irrigation.[3]

§ 25. **Seepage water—Effects of.**—One of the first effects of seepage noted in irrigation where the soil is pervious, is the filling of the subsoil with water. Evidence of this is found in the gradual rising of the water in the wells which may have been sunk in the region affected. Throughout any country where irrigation is practiced, the evidence is ample, for as the application has been made within a single generation, the changes which have ensued from the application of water are within the memory of many living observers. Take, for example, in many places where it was originally forty to fifty feet to the water in the wells of the region, water now stands from ten to twenty feet from the surface, the subsoil of the region having been filled to that point. There is

2 See Water-Supply and Irrigation Papers No. 7, p. 11; Bulletin No. 33, Agricultural Experiment Station of Colorado.

3 For the drainage laws of the various States, see Part 14; The Reclamation of Seeped and Alkali Lands, by C. F. Brown and R. A. Hart, 1910, Bulletin No. 111, Utah Agricultural College Experiment Station; Reclamation of Alkali Lands in Egypt, by Thos. H. Means, 1903, Bulletin No. 21, U. S. Dept. of Agriculture.

sometimes a lowering during certain seasons of the year, due to the suspension of irrigation on the land above, and also due to the lateral passage of the water. If the irrigation on the land above is continued for a long period, in many places, the lateral passage of the water has had the effect of filling in the ground higher and higher until the water appears on the surface, thus rendering it unfit for cultivation and capable of growing only tules, sedges, cat-tails, and other water loving plants. Also sometimes upon the evaporation of the water, a deposit of alkali is left, thus rendering what was formerly called the best agricultural lands entirely unfit for cultivation without drainage. These effects usually appear near the canal at first, and year by year are found farther and farther away from the canal, or from the irrigated locality, as the case may be. In course of time the waters which are thus percolating through the subsoil reach a depression, or a stream, and increase the waters passing therein, and in turn may be, and often times are, diverted again for the irrigation of lands lower down.

The effects of seepage as far as this work is concerned may be therefore summed up in two classes: Beneficial and injurious; beneficial, by increasing the available water supply of a section of the country; injurious, by rendering land, that formerly was good and in a state of cultivation, worthless by reason of water-logging or the alkalies that are deposited upon the surface. Of course these injurious effects upon lands that underlie irrigation canals and irrigated lands have given rise to a great deal of litigation in the courts for damages for injuries to land from "seepage," which include both water-logging,[1] and alkali, which subjects will be discussed in their proper places in this volume.[2]

§ 26. **Evaporation—Definition and description.**—Evaporation, as the term is known in irrigation parlance, is the conversion of the water or moisture in the soil, or from water surfaces into vapor, by the agency of natural heat. The large loss by the annual evaporation from wet ground surfaces of an arid region is of a far greater economic importance than is the question of the evapo-

1 See post Secs. 1206, 1207. See, also, Damages from Seepage; Injunctions against Seepage.

2 See Underground Waters, Chaps. 59-62, Secs. 1148-1211.

ration which takes place from water surfaces, for the reason that, in a greater measure, it can be controlled by man. Such a conservation of the available water supply of any district results in having a balance, which can be utilized in the reclamation of other lands and in increasing the production of the lands now cultivated. The subject of evaporation will be discussed from another phase of the question when we get to the chapter upon the economical use of water and the suppression of waste.[1]

But from the economic standpoint, the loss of an excessive amount of water by evaporation injuriously affects both the farmer who has an available supply of water for irrigation, and the one who cultivates his land dry, at the same time needing water. All other taxes paid by the farmer are small to the one levied by the atmosphere in robbing the soil of its much needed moisture. The magnitude of this loss borne by irrigators is enormous. It has been estimated that between seed time and harvest of each year there is sufficient water spread over the lands in the arid West to cover all of New England a foot deep. In some sections of the country this water is still cheap, but in others it is very expensive, more particularly in sections where the population is comparatively dense. The annual cost to the farmers in the maintenance of the works for applying so much water probably exceeds $25,000,000, not taking into consideration the original cost of the rights. It is also estimated that at least 40 per cent of this water which costs so large a sum is lost each year by evaporation from the surface of the fields where it is applied. The loss to any farmer, in failing to get a portion of this water, is in diminishing yields. He is dependent largely upon the natural rainfall, which in this portion of the country is exceedingly slight during the cropping season; and, as a rule, his crops are good or poor in proportion to the amount of water retained in the soil and conserved from previous precipitation during the preceding winter or spring. Every acre inch of water which is retained and prevented by any means from passing into the atmosphere will assist in producing

1 See Chap. 49, Secs. 874-916.

See subject of evaporation in article by Bailey Willis of the U. S. Geological Survey, Vol. 2, pp. 690, 691, Report Nat. Conservation Commission, 1909; Evaporation Losses in Irrigation and Water Requirements of Crops, by Samuel Fortier, 1907, Bulletin No. 177, Office Experiment Stations, U. S. Dept. of Agriculture.

largely augmented crops upon a specific tract of land, besides greatly adding to the acreage which may be cultivated with the available supply of water. At best there is only water enough to irrigate a part of the fertile, arable land of the arid West; and, therefore, for every acre that is irrigated there are many acres which must of necessity be farmed dry, if they are farmed at all. The saving of water by the means of preventing an excessive evaporation has been given considerable study in this and other countries, some of the methods of which will be discussed in the following section.[2]

§ 27. **Evaporation—How prevented.**—How best to conserve the soil moisture over so vast an area, comprising both the dry and irrigated farms of the arid West, is a question which deserves the thoughtful consideration of every Western farmer; and in time, as the population of that region increases, will become a question of great National importance. For a number of years investigations have been carried on by the Office of Experiment Stations of the United States Department of Agriculture for the purposes of determining the extent of the loss by evaporation of moisture from the soils, and the best methods of preventing a portion of such loss. The experiments reported show that the conditions having the greatest influence on evaporation from soils are the quantity of water in the top soil, the temperature of the soil and water, and the wind movement. All of these can be controlled to a large extent by the irrigator by his methods of applying water and by subsequent cultivation of the soil. The application of the water in such a way as not to wet the top soil decreases the quantity of water in the top layer, and at the same time places the moisture in the soil beyond the influence of wind movements, and, to a considerable extent, beyond the influence of high temperatures of unusually hot days. The daily variations in temperature almost disappear at a depth of one foot, the decrease in temperature being very rapid on hot days. The amount of water evaporated from the soil depends largely upon the wetness of the soil, but the proportionate saving with reductions in temperature is probably as great as from water surfaces. From experiments made by the United States Department of Agriculture for a num-

[2] See Sec. 27.

ber of years, the following methods of applying the water have been found to conserve portions of the same: First, by applying the water at night, when the soil is cool and when there is an absence of the sun's rays, thus permitting the water to sink before there is a great opportunity for evaporation;[1] second, by applying the water at a sufficient depth to keep it from coming in contact with the hot surface layer of the soil, which can be accomplished by applying the water in deep furrows or by sub-irrigation;[2] third, by cultivation of the top soil. The frequent cultivation maintains a mulch of loose soil at the surface, which prevents the excessive heat of summer from reaching the moist soil, as well as destroying capillarity.[3]

When we come to the subjects of "wasting water," and "duty of water," the subject of evaporation will be discussed from the legal standpoint of preventing waste.[4]

1 This method, although not always practicable, where it can be used permits the water to soak into and thoroughly saturate the ground before the heat of the day, when the evaporation is the greatest.

2 For sub-irrigation, see Sec. 36.

See, also, Primer of Irrigation, Anderson, 1905, Chap. 15, p. 173; U. S. Department of Agriculture, Experiment Stations Bulletin No. 177, by Samuel Fortier.

One of the important features of the work of the Bureau of Soils, a bureau in the Department of Agriculture, during the past few years is the investigation of the movement of water in the soil. It has been heretofore supposed that the root of a plant is fixed in the soil and that the water, with the food material which it contains, moves up to the root in a constant supply through capillary action. It has been found, however, in measuring the rate of movement of water in a soil moderately dry or in a fair condition as regards the needs of plants that the movement is so slow as to be negligible. From a little experiment this is easily ascertained. Take some soil from the field with what is called an optimum of moisture, or the best amount for plant growth, put it in a tumbler, filling the tumbler about half full, and put some dry soil on the surface. The difference can be easily seen, as the moist soil will be darker than the dry. Then if the tumbler is covered to prevent evaporation the dry soil can be left in contact with the moist soil and there will be no appreciable interchange of moisture between the moist and the dry layers. The moist earth will hold on to the water so tenaciously that the dry earth will not pull it away. So by cultivation the top layer of the soil becomes loose and the moisture is easily evaporated from it, but at the same time the dry top soil thus produced, served as a protection to the moist soil below as the capillary attraction is destroyed. See Farmers' Bulletin No. 257, U. S. Department of Agriculture.

3 See, also, Sec. 32.

4 For the economical use of water and the suppression of waste, see Chap. 43, Secs. 874-916.

§ 28. Transpiration—Nature and description of.—In an arid country agricultural products are almost entirely dependent upon the water supply. As a rule, the soil is fertile, containing in abundance the elements necessary for the development of plants; but if the water supply be either deficient or in excess, or applied at the wrong time, a partial or no growth will result. Vegetation requires water: First, to enable it to feed. Unless the soil is sufficiently moist the fine roots can not extract those chemicals which are necessary for the growth of the plant. Second, to furnish the sap and the water in the fruit or grain, whatever it may be. Third, to evaporate, or, rather to transpire. The amount of water required for the two first is very small as compared with what the plant evaporates. A plant, especially in hot weather and a dry atmosphere, throws a vast amount of water from its pores; it can not dispense with water, and unless fully supplied with it at the right time it will fail in its object. But by a proper irrigation method the proper amount of moisture is maintained in the soil, the plant is kept healthy, and in a vigorous condition, and the normal amount of water passes through its tissues by transpiration, bearing the necessary mineral food furnished by the soil. The sage brush and native grasses indigenous to the uncultivated region of the Rocky Mountains require but little moisture to maintain their slow growth. In certain sections of the arid region of this country the annual rainfall does not exceed from ten to fifteen inches per annum. Very little snow remains for any length of time on the ground; the evaporation in summer is excessive on all moist ground and water surfaces; and yet the sage brush flourishes, growing from a height of from three to ten feet. If we deduct from the total yearly precipitation the probable amount of moisture evaporated from the surface of the ground, very little will remain for the use of plants. It is possible that the total quantity of water absorbed by the roots of the plants that grow on the wild lands of the arid region and retained in the plants or transpired by their foliage does not exceed one-tenth of the annual precipitation. The magnitude of this transpiration of water through the foliage of plants, not native to the arid region, has been estimated by various scientists, through long series of experiments. And it is shown, for example, that 330 tons of water will be absorbed by the roots of clover, drawn up through the

stems, and transpired from the breathing pores of the leaves, for each ton of clover harvested. If the yield be estimated at three tons per acre, the quantity of water per acre is 990 tons, or a volume sufficient to cover the surface to a depth of nearly nine inches. The transpiration of many other forage and grain plants has also been estimated with similar results.[1]

No method has been discovered by science, whereby transpiration from plants may be lessened at a saving of water, without injuring the plants. Only Nature is able to regulate her requirements in this respect.

§ 29. **Supplemental irrigation—Definition and benefits.**—The irrigation of lands in a humid region, where theretofore it had been supposed there was a sufficient rainfall, or the irrigation of lands in a semi-arid or sub-humid region, where there is a more scanty rainfall but sufficient in some seasons to bring crops to maturity, is termed "supplemental irrigation," inasmuch as it supplements the rainfall or makes good its deficiency and the uneven distribution during the periods of the crop growing season.

Formerly when the subject of irrigation was broached to an Eastern man, he immediately thought of an arid region, or one in which the ordinary rainfall during the summer months is insufficient to raise a crop to maturity or to raise one sufficiently profitable. In an arid region irrigation is practiced all the time, from the planting of the seed to the maturity of the crop, and even afterward it is necessary to again irrigate for the purpose of fitting the soil for the planting of the next crop. As a general thing the rainfall is totally disregarded, for the reason that it is not to be depended upon during the summer months. Irrigation there

1 See Water-Supply and Irrigation Papers No. 7, p. 24; F. H. King, Agricultural Experiment Station, University of Wisconsin, 9th Annual Report, 1892, p. 94; Dept. of Agriculture, Experiment Station Record, Vol. 4, p. 532.

See, also, Primer of Irrigation, Anderson, 1905, Chap. 17, p. 194; Factors Influencing Evaporation and Transpiration, by John A. Widsoe, Bulletin No. 105, Utah Agricultural College Experiment Station.

As to the relation of transpiration from forests to stream, see the chapter of Forests as Related to Stream Flow, Chap. 2, Secs. 40-62; The Relation of Forests to Stream Flow, by James W. Toumey, collaborator, Bureau of Forestry Yearbook, 1903, U. S. Dept. of Agriculture; Economics of Forestry, pp. 121, 437, 438, Fernow.

is an absolute necessity; and, therefore, all preparations are made for the same by the construction of the necessary works and keeping them in repair in order to utilize the water. But, during the more recent years, irrigation has been looked upon with more favor in portions of the country other than within the arid region. This is especially true in some portions of the South, and in some portions of the Middle West.

Even in the regions where the rainfall is usually ample for the growth and ripening of the fruit or crops the art of irrigation is becoming each year more and more a valuable adjunct to the natural rainfall. The satisfaction of knowing that the labor of a season will not be rendered void because of a week of drought coming just at the time when the plants need the moisture most, is one that can not be too much appreciated. The normal condition of the average farmer who depends upon the fall of rain is one of anxiety. He must wait for rains in order to plow, to sow, to cultivate. His work is often delayed because they do not come. The farmer who irrigates has the water under control. He turns on the amount needed, and at the time needed, and fits his land readily for any of these operations. He is sure of his supply of water, regardless of the condition of the weather. Should the rainfall be sufficient to supply the necessary moisture he needs only to suspend his irrigating operations for the time being.[1] Supplemental irrigation, though quite recent in the United States, and even now looked upon with disfavor in some portions of the Eastern part of the country, has been practiced in Europe and Asia for centuries, in those portions where the average rainfall is sufficient to raise crops without irrigation, as in our humid regions. In Germany, France, Italy, and even in the British Isles, it has been practiced with profit and success. But where it is of the most value, outside of a strictly arid region, is in the semi-arid, or as sometimes called, the sub-humid regions. In these regions, the rainfall is very fickle and uncertain both as to time and quantity. Some seasons there may be plenty of rainfall and at the right season of the year, so that large crops are grown and matured. Then will come a season of "dry spells," and then

1 See the chapter on Supplemental Irrigation in the Primer of Irrigation, Anderson, 1905, Chap. 16, p. 187; Irrigation in the North Atlantic States, by A. G. Bowie, 1906, Bulletin No. 167, U. S. Dept. of Agriculture.

another and another, so that the crops are absolutely ruined, or a very small crop comparatively is matured. Or there may have been a sufficient annual precipitation to raise crops, but it may have all come in the winter, or early in the spring when it was not needed; and there being no system of storage of this precipitation, it of course all runs off; and when the summer comes and the rain is needed the skies are as of brass and the earth like a burning furnace.

Supplemental irrigation has also been recognized in the Eastern and Middle States of this country, in the New England States, Illinois, Minnesota, Wisconsin, South Carolina, Louisiana, Alabama, and Georgia. While in that tier of States the western portion of which at least is semi-arid, composed of North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas, the value of irrigation is known, as supplemental to the rainfall, and large irrigation plants are established, and are in operation. To state the proposition of supplemental irrigation succinctly, it removes the element of chance in all farming that depends solely upon water precipitated from the clouds upon the crops during the summer season.[2]

There is one fact which may be mentioned as the reason why supplemental irrigation is not more practiced in this country, and that is the general unprepared condition of the farmers, when the time comes that they need the water. In many sections where it could be used to advantage and profit, no works are constructed to utilize the water. When it rains, they do not need such works, and when they need the water they have not got the works to divert and conduct the water to the fields where it might be used.

§ 30. **Irrigation and its many methods.**—The methods of the practical workings of irrigation are today many and various. As the years have gone by and we have come to the early part of the twentieth century, by careful research and enlarged observation fully considered, and based upon the experience of ages in different countries, the practical workings of irrigation in some parts of the world have been so highly improved as to have become almost an exact science; or, at any rate, they have acquired a

2 This subject will be more thoroughly discussed under the subject, History of Irrigation, Secs. 63-87.

distinct scientific character. However, their particular features greatly vary; indeed they are so unlike in different countries, and in different climates of the same country, as hardly to permit us to view them in the same light. Looking toward the far East, on the banks of the Tigris and Euphrates, we find the patient, plodding oxen laboriously raising the water from the streams, in buckets made of bullock skins, called lifting water by "bag, or mot." Throughout India, Asia Minor, and Egypt, we also find the "Persian wheel" driven by bullocks for the same purpose. In many localities in India and Egypt, we even find more primitive methods such as the "shaduf," or "shadoof," the "Archimedian screw," the "natali," the "double zigzag balance," the "doon, or tilting trough," the "swinging basket, or latha," the "paecottah," resembling the farmer's well sweep, and many other crude devices, all worked by the hand of man.[1] The machinery used in irrigation operations, in many parts of the world, is still of the crudest possible character; yet, with this aid, the water is raised to the surface and is poured into small trenches, which readily conduct it to the thirsty patches of soil under cultivation. And, furthermore, it is from such primitive examples as these that great lessons have been learned, in the practical operations and the results of cultivating the land by means of irrigation. Over in India,[2] Egypt,[3] Italy,[4] and a number of other countries of the old world, we find immense canals, aqueducts, and reservoirs, constructed by the respective Governments at enormous expense, and with the highest possible degree of human skill, always looking toward the permanency of such structures. Here whole provinces have been reclaimed from their natural wild state, and converted into the most fruitful regions of the earth.[5] In our own country, thousands of miles of main canals and laterals and great reservoirs are already constructed, and many more under the process of construction. This has been and is being done both by

1 See Pumping Water for Irrigation, by Herbert M. Wilson, 1896, Water-Supply Paper No. 1, U. S. Geological Survey; Décret et Reglèment concernant les Machines Élévatoires, Avril, 1881, Ministère des Travaux Publics, le Caire, Imprimerie Nationale, 1907.

2 For Modern Irrigation in India, see Secs. 103-118.

3 For Modern Irrigation in Egypt, see Secs. 88-102.

4 For Modern Irrigation in Italy, see Secs. 144-159.

5 For Modern Irrigation in Various Countries, see Secs. 160-176.

private enterprise and by the National Government, under the provisions of the Reclamation Act, and in some instances by States.[6] The United States has alone expended $51,000,000 on Federal irrigation systems, and this amount is far exceeded by private enterprise.[7] In many parts of this country, especially where the land is practically level, and the water is found in channels somewhat below the adjoining land, many modern pumping plants have been installed, operated by steam, wind, gasoline, or electricity, whereby the water is raised to the level of the land and conducted by ditches and canals to the place of use.[8] Owing to the recent scientific investigations, the movements of subterranean or underground waters have become known and defined; and, therefore, these waters are beginning to be utilized by means of artesian wells,[9] pumping plants, or by concrete dams constructed below the surface so as to obstruct the water and force it to the surface.[10]

And, although great ingenuity and skill, and great diversity in the operation of these various systems appear, we do not hesitate to pronounce them all justly included under the one great art of irrigation. The shepherd who properly directs the course of a mountain streamlet in order to prevent stagnation and waste, and, of course, to promote the health of himself and of his flocks, and at the same time directs the waters in such a manner as to fertilize barren spots of soil and thus furnish additional supplies of food, really belongs to the same class of artizans as those who, by most elaborate surveys, skillful engineering, and enormous

6 For this Act, see Chap. 65.

7 See Water-Supply Paper No. 276, by W. B. Freeman and R. H. Bolster, 1911, U. S. Geol. Survey.

See, also, the Annual Reports of the Reclamation Service, up to and including that of 1912.

See, also, the Biennial Reports of the State Engineers of the respective States of the Arid West up to and including those of 1911.

See, also, the subject of irrigation as discussed by F. H. Newell, Director of U. S. Reclamation Service, Vol. 2, pp. 59-66, Report of National Conservation Commission, 1909, and the same in Water-Supply Paper No. 234, U. S. Geol. Survey.

See, also, the same subject discussed by Samuel Fortier, Chief Irrigation Investigations, U. S. Dept. of Agriculture, Vol. 2, Rept. National Conservation Commission, pp. 67-73.

8 For Pumping Water for Irrigation, see Secs. 1201, 1202.

9 For Artesian Wells, see Secs. 1168-1170.

10 For Subterranean Waters, see Secs. 1148-1211.

capital and labor expended, are able to direct to the most useful ends the vast inundations of tropical rivers. The particular features in the operation of irrigation are different, but the result is the same, the cultivation of land by the best method, for the production of the food for the world.

§ 31. Irrigation methods—How water obtained from natural sources.—The first step toward the irrigation of lands is to acquire the right to the use of water from natural source of supply. The main portion of this work discusses how such rights are acquired, maintained, and protected, and will be thoroughly discussed hereinafter. The second step in the procedure is to construct the necessary works to utilize the water covered by such rights. There are numerous methods whereby the water is taken from the natural sources of supply and finally conducted to the place where it is to be applied to the soil for the irrigation of the same. The method of taking the water from the natural source of supply is immaterial as far as its final application to the soil for the purpose of irrigation is concerned. The most common method of obtaining the water is the damming of natural streams in such a manner as to divert the water therefrom into canals, ditches, or flumes, through which the water is conducted to the place of application. The outlets of lakes or ponds are sometimes dammed, the waters of the same thus raised so that they may be tapped by the canals and ditches.[1] Or, in certain localities the water is obtained by the sinking of artesian wells of a depth sufficient to strike an underground reservoir, from which by its own pressure from above it is forced to the surface of the ground and from thence conducted to the place of use in the usual manner.[2] Also by the

1 For canal construction, see Irrigation Engineering, by Herbert M. Wilson; Irrigation in the United States, by F. H. Newell, 1906; Irrigation and Drainage, by F. H. King; Irrigation Farming, by Lucius M. Wilcox, 1910, Chap. 6, pp. 57-83; see, also, Pipes for Irrigation Purposes, Chap. 8, pp. 109-122; also, Flumes and Their Structure, Chap. 9, pp. 123-139, same Work.

2 For artesian waters and wells, see Subterranean Waters, Secs. 1166-1184.

See, also, Contributions to Hydrology of Eastern United States, Water-Supply Papers Nos. 102, 110, and 145, and Underground-Water Papers, Water-Supply Paper No. 160, by Myron L. Fuller.

See, also, Underground-Water Papers, Water-Supply Paper No. 258, 1911, by M. L. Fuller, F. G. Clapp,

damming of the streams, especially where the fall is slight, the bottom lands may be flooded or inundated, as is the case of the rice fields of the Southern States, China, and Japan. Water wheels and current motors are sometimes used, where, by the force of the current of the stream itself, a small portion of the water is lifted to an elevation, where it can be run into the ditches.[3]

As much of the flow in the natural streams in this country during the summer time when the water is needed the most for irrigation is already appropriated, the construction of reservoirs for the appropriation and storage of the surplus or flood waters is becoming more common each year. By this means the water which would naturally run to waste during the winter and spring seasons is utilized, without interfering with the rights of those who have appropriated the natural flow of the streams during the cropping season. The water thus stored is let down by the means of ditches and canals, and sometimes through the natural stream itself, to the place where it is applied for use.[4] Nearly all of the Western States have special statutes upon the subject of reservoirs and reservoir rights.[5] Pumping plants of various kinds, propelled by steam, gasoline, electricity, or wind, are frequently resorted to, whereby at times great quantities of water are pumped from a stream, lake, or wells, as the case may be, to such an elevation as will permit the water to run by gravity to the place or places of use. In all parts of the arid and semi-arid regions are to be found these various sorts of pumps utilized for this purpose. The United States Government has taken the pains to investigate various kinds and makes of pumps, the merits of which will be found in the bulletins issued from time to time.[6]

G. C. Matson, Samuel Sanford, and H. C. Wolff; Underground Waters, by W. C. Mendenhall, Water Resource Branch U. S. Geological Survey, as part of the report in Vol. 2, pp. 86-94, of the National Conservation Commission, 1909; same in Water-Supply Paper No. 234.

[3] For the right to use the current for the purpose of lifting water, as against other appropriators interfering therewith, see Sec. 724.

[4] See for reservoirs and ponds, Irrigation Farming, by Lucius M. Wilcox, 1910, Chap. 7, pp. 84-108.

See, also, for Reservoir and Reservoir Rights, Chap. 46, Secs. 837-846.

[5] For the statutes upon reservoir and reservoir rights, see Part 14.

[6] See Pumping Water for Irrigation, by Herbert M. Wilson, 1896, Water-Supply Paper No. 1, U. S. Geol. Survey; Irrigation Practice on the Great Plains, by E. B. Cowgill, 1897, Water-Supply Paper No. 5, U. S. Geol.

§ 32. Irrigation methods—The application of the water to the soil.—After the water has been conducted to the fields or places of use, it must be applied to the soil in an economical manner consistent with the best crop production, and the rights of others who are also entitled to the use of water from the same source of supply.[1] There are a number of methods of the application of

Survey; Windmills for Irrigation, by E. C. Murphy, 1897, Water-Supply Paper No. 8, U. S. Geol. Survey; Underground Waters for Farm Use, by Myron L. Fuller, Water-Supply Paper No. 255, U. S. Geol. Survey; Cost of Pumping from Wells for the Irrigation of Rice in Louisiana and Arkansas, by W. B. Gregory, 1908, Bulletin No. 201, U. S. Dept. of Agriculture; Mechanical Tests of Pumping Plants in California, by J. N. Le Conte and C. E. Tait, 1907, Bulletin No. 181, U. S. Dept. of Agriculture; Tests of Internal-Combustion Engines on Alcohol Fuel, by C. E. Lucke, and S. M. Woodward, 1907, Bulletin No. 191, U. S. Dept. of Agriculture; Mechanical Tests of Pumps and Pumping Plants, by W. B. Gregory, 1907, Bulletin No. 183, U. S. Dept. of Agriculture.

See, also, for pumps and irrigation machinery, The Primer of Irrigation, Anderson, 1905, Chap. 19, pp. 209-218.

Also, see the most excellent chapter on Windmills and Pumps, in Irrigation Farming, by Lucius M. Wilcox, 1910, Chap. 17, pp. 352-393.

[1] For the economical use of water and the suppression of waste, see Chap. 49, Secs. 874-916; Primer of Irrigation, Anderson, 1905, pp. 194-208; Irrigating the Farm, Wilcox; Irrigation Farming, Wilcox, 1910, Chap. 11, pp. 166-205; Irrigation for Farm and Garden, Stewart; Practical Information for Beginners in Irrigation, by Samuel Fortier, 1906, Farmers' Bulletin No. 263, U. S. Dept. of Agriculture; Preparing Land for Irrigation and Methods of Applying the Water, prepared by agents of irrigation investigation, under the direction of A. C. True, Director, Bulletin No. 145, Office of Experiment Stations, U. S. Dept. of Agriculture; Distribution of Water in the Soil in Furrow Irrigation, by R. H. Loughridge, under the direction of Samuel Fortier, Chief of Irrigation Investigations, Bulletin No. 203, Office Exper. Stations, U. S. Dept. of Agriculture.

See, also, the many other bulletins issued for distribution by the United States Government, catalogues of which may be had from the Department of Agriculture, the Interior Department, or from the Superintendent of Public Documents, Washington, D. C.

For the measurement of water, see Secs. 888-900.

For the duty of water, see Secs. 902-908.

See, also, for the duty and measurement of water, Irrigation Farming, by Lucius M. Wilcox, 1910, pp. 140-165.

For the relation of soils to irrigation, see Irrigation Farming, by Wilcox, 1910, Chap. 3, pp. 22-35; Primer of Irrigation, Anderson, 1903, Chap. 5, pp. 54-66.

Also, see the many bulletins issued by the Bureau of Soils of the U. S. Dept. of Agriculture, upon the subject of soils.

water to the soil. These usually vary according to the varying conditions of the soil, climate, etc., and the habits and customs of the irrigators of any particular locality. And, in general, it may be said that, in many sections of the country many irrigators, where not restrained by law and State supervision of the distribution,[2] in seeking to hold the right to the use of a certain quantity of water, apply too much water to their lands; and, thereby, they not only injure themselves, but also their neighbors, who are being deprived of its use. Even in this present time, there are too many farmers who attempt to cultivate their lands merely by the application of water, when a little greater exertion upon their part in plowing a little deeper, or in following a cultivator more assiduously, would not only benefit their lands, but would probably not injure themselves. They flood their lands with water, and when the top soil bakes under the rays of the sun, they apply more water to soften it up; this process being kept up indefinitely; when, if there had been more cultivation, and less water applied, a greater and better crop yield would have been had, and, at the same time, the water would not have been wasted. It should be remembered that a frequent cultivation maintains a mulch of loose soil at the surface, which prevents the excessive heat of summer from reaching the moist soil, as well as destroying capillarity.

It is not within the province of this work to discuss to any great extent the practical side of irrigation, and we shall not do so except in so far as this side relates to legal principles involved in the subject. But, as the methods of the application of the water to the soil for irrigation involves also the questions of wasting of water and "duty of water," it is necessary to discuss in a most general manner the various methods that irrigators have of applying the water to the land, after it has once been brought to the place of use.

As the Western portion of this country has become more and more settled up, by the great influx of settlers from other portions of this and foreign countries, the demand for water for irrigation of lands has each year become greater and greater. In many sections of the country the available water supply has become entirely inadequate for the present demand, and all of the known

2 For the Law of State Control and the State administration of waters, see Chap. 68.

sources of supply have become utilized to their fullest possible extent. Hence it must necessarily follow that, if agriculture is to be extended in these sections, the only method by which it can be extended, is by a more economical use of the available water supply, and the absolute suppression of all waste. Some of these methods, however, are as economical and tend to produce the greatest crop results to the irrigator, and also to promote the greatest good to the greatest numbers in that community where the water is so used. Other methods of application are wasteful in the extreme, and tend to an actual injury in crop results to the owner, and also to rob others, who might make use of the water on their lands had a more economical method been pursued. This, of course, is an injury to such individuals, to the whole community, to the State, and, in turn, to the Nation, and has become a serious question in economics. Fortunately, the most of the States have taken up this matter, and by legislation prohibit the wasting of water, and provide for its economical distribution by State officials. The courts, also, when this matter has been properly brought before them, have as a general thing, upheld these laws, as a part of the police laws of the State, and have taken steps, by their decisions, to suppress the wasting of water, and the application of water to the ground by wasteful methods.[3]

§ 33. **Methods of irrigation—Classification.**—Where water is poured into or upon the soil, gravity first draws it downward; the particles of earth seize upon what they require, and the surplus water continues to descend until it reaches an impervious stratum or a water table, or is carried off through the drainage of the system. Then the capillary action begins, and the moisture ascends, and it and the nutritive elements that it has gathered from the soil are seized upon by the roots of the plants and absorbed. The main question is ever: By what method or methods of the application of the water to the soil will the roots absorb the moisture and nutritive elements so as to produce the most healthy growth of the plants and its fruit?

There are a great many methods of applying water to land for

[3] See, also, The Adjudication of Water Rights; The Protection of Water Rights by Injunction and by Other Actions; The Damages to Water Rights.

irrigation, but they may be classified into four main systems, which are as follows:

First. Flooding the land or check system. This is where the water is made to cover the land entirely at any desired depth, and, according to the nature of the crop, is either allowed to remain stagnant, or stationary, or to pass off with a slight current.

Second. Flowing, ditch, or furrow irrigation. This is where the water is run over the land through ditches or furrows in close proximity to the plants.

Third. Infiltration, seepage, or sub-irrigation. In this method the water is carried to the roots of the plants by means of deep, open ditches, or by subterranean waterways laid for that purpose.

Fourth. Aspersion, or sprinkling. This is where the water is applied in a shower, or as an imitation of rain. Watering with a common sprinkling pot, or rubber hose, will give an idea of this system.[1] These systems are divided into many subdivisions, which vary according to the nature of the soil, climate, source of water supply, customs of the country, and those brought from other countries, and last, but not least, according to the individual so using the water.[2]

We will briefly discuss these methods in the above order in the following sections.[3]

1 See Anderson's Primer on Irrigation, Chap. 13.

2 "The diversity in irrigation methods in use on Western farms is largely due to the early training and environment of the irrigators themselves. Among the 120,000 irrigators of Western America are to be found nearly all classes and nationalities. Each settler from another State or from a foreign country introduces on his farm some custom or practice common to his old environment. This is particularly noticeable in the conservative Chinese, who irrigate the truck gardens near the towns and cities in Chinese fashion. The same is true of the Italians, Spaniards, and Mexicans, who imitate, for a time at least, the ways of their forefathers. It also applies, but to a less degree, to those who come from humid States. The farmer who lives until maturity in the Mississippi Valley and then moves West onto an irrigated farm does not as a general thing adopt new ways of farming until crop failures compel him to do so. Even then the old ways of doing things are mixed with the new."—Preparing Land for Irrigation and Methods of Applying Water, Bulletin No. 145, Office Experiment Station, U. S. Dept. of Agriculture.

3 See Secs. 34-37.

§ 34. **Methods of irrigation—Flooding land.**—Irrigation by flooding is simply submerging the tract of land, by covering it with a sheet of water more or less deep, and allowing it to remain upon it a certain time, to "soak" into the soil before drawing it off. On flat or level ground, preparations for submersion are simple and easy, and simply consist of the throwing up of ridges of earth or dikes around the edge of the tract to retain the water. After the ground has soaked for a time, the water is let out from the first tract, enclosed by the dikes, into another tract, and the process is continued until the whole field has been covered.[1] The flooding of land in checks or compartments is the same system and has been practiced from the earliest antiquity. It was introduced into this country by the Spaniards, Mexicans, and the Mexican Indians. It is also sometimes called basin irrigation. The size of the checks varies greatly in different portions of the country, and according to the nationality of the irrigators. The Mexicans construct from ten to fifty checks on a single acre, while in some sections, Americans, in order to conduct operations upon a large scale, have increased the size of the checks to from ten to thirty acres each.[2] This method has its advantages and disadvantages. It can not be used in a country where there is considerable slope to the land, without a great deal of labor in preparing the land, as the land in each check must be level, or the high places will receive no water, and the lower places receive too much. The method should be adopted or rejected according to physical conditions. Yet in the face of many difficulties whole communities cling to this method. It has been said that: "Such farmers are like cobblers who attempt to make all shoes on one last."[3] The most important disadvantages, as far as this discussion is concerned, is that this method requires more water than is required under any other system, and the beneficial results are no greater. In certain crops the method, because of the embankments thrown up to retain the water, to a certain extent prevents cultivation, so necessary to any such crop in all countries, and especially where

[1] Primer of Irrigation, Anderson, 1905, p. 158.

[2] Preparing Land for Irrigation and Methods of Applying Water, Bulletin No. 145, 1904, Office Experiment Stations, U. S. Dept. of Agriculture, pp. 28-35, 79-83.

[3] Preparing Land for Irrigation and Methods of Applying Water, Bulletin No. 145, *supra*.

the land is cultivated with the aid of irrigation. Other crops which can not be cultivated, such as alfalfa, although it requires a great volume of water to operate successfully, receive great benefit from this method.

Professor Schwerz, in his treatise on practical agriculture, in summing up the advantages and disadvantages of the flooding or submersion system, concludes: "Finally, to inundate a large field rapidly throughout its entire extent is to consume an enormous amount of water." It requires much more water than is allowed under the "duty of water" under many of the United States Reclamation projects, or by the laws of many of the States fixing the duty. And its operation may be considered, in these times, when a most economical use of all of the water supply is required, in many instances, as a method of wasting water by adhering too closely to ancient customs and traditions.

§ 35. Methods of irrigation—The ditch or furrow method.—Probably the most common method of applying water to the soil after it has been brought to the place of use is by the ditch, trench, or furrow method.[1] This method is more especially adaptable to all conditions of the country and lands, where there is sufficient slope to permit the water to run freely. And it is more generally used in larger enterprises than are other methods, for the reasons that it takes less water to irrigate the same area, and the water is more easily handled. It is a distinct saving of water over the flooding method discussed in the last section.[2] It may be adapted to much more uneven land, and, when the kind of crop permits it, it permits of cultivation. It is better adapted to lands which have considerable slope, as where there is little fall the water be-

1 See Preparing Land for Irrigation and Methods of Applying Water, 1904, Bulletin No. 145, Office Experiment Stations, U. S. Dept. of Agriculture; Distribution of Water in the Soil in Furrow Irrigation, 1908, by R. H. Loughridge, under the direction of Samuel Fortier, Chief of Irrigation Investigations, Bulletin No. 203, same; Practical Information for Beginners in Irrigation, 1906, by Samuel Fortier, Farmers' Bulletin No. 263, U. S. Dept. of Agriculture.

See, also, the many bulletins issued by the Dept. of Agriculture, upon this and kindred subjects, and those issued by the State Agricultural Colleges and Experiment Stations, catalogues of which can be had for the asking.

See, also, The Primer of Irrigation, Anderson, pp. 157, 158.

2 See Sec. 34.

comes stagnant on account of the ditches overflowing. But it may also be used for the raising of crops which can not be cultivated. And for this purpose, small dams often made of canvas are used in the small ditches and trenches running through the fields. This permits the water to overflow, and, in a measure, floods the fields; afterward, the dams are removed and the water permitted to drain off through the system of ditches prepared for that purpose, thus preventing stagnation. By the furrow method the loss of the water by seepage and evaporation is lessened, as the soil is moistened chiefly from capillarity from beneath the surface. The greater portion of the water thus applied is absorbed by the soil and the plants in such a manner that it produces the greatest results. A small head can be conveniently and advantageously used, by using fewer furrows at the same time; and a larger head may be used by permitting the water to flow through more furrows. The alkali is less liable to rise to the surface, and the land is not so subject to baking. It may be cultivated, new furrows being marked off by an implement for that purpose, so as to be ready for the next watering. And, above all, there being a less loss of water by this method, a greater area may be irrigated by the same volume, than there can be by the flooding method. This insures a greater duty of the water and a more economical use.

§ 36. **Methods of irrigation—Infiltration or sub-irrigation.**—The third of the more common methods of applying the water to the soil is that of infiltration, seepage, or sub-irrigation. By this method the water is applied directly to the roots of the plants by the means of deep open ditches or trenches, or by subterranean pipes or conduits laid for that purpose.[1] It is better adapted to horticulture than to general agriculture. It is also used in truck gardening. It can not be operated in clayey, impervious soils, and only where the soil is sandy or gravelly.

This method possesses the advantage over surface irrigation only in the saving of water, and in this there is a decided advantage, especially where the water is very scarce, and none must be wasted. While sub-irrigation has been practiced in different parts of the country, especially in California, it has never proved entirely satisfactory. But experiments of the United States Depart-

1 Primer of Irrigation, Anderson, 1905, p. 165.

ment of Agriculture tend to show that a large conservation of water might be made if sub-irrigation could be made practicable, and at a minimum expense. But the expense of this method is heavy. It costs a considerable sum of money to lay out a field and to run a pipe line underneath the ground for each row of trees and to have a faucet or opening at each tree. However, it is operated to a considerable profit in some localities for the cultivation of citrus fruits and in gardening, where every foot of ground is cultivated and every inch of water utilized. And, as the demand for water becomes yearly greater, there may come a time when this method will be more in vogue.

In this connection especially for the benefit of the so-called scientific dry farming, much study has been made of the question of the storage of water in the soil.[2]

§ 37. **Methods of irrigation—Aspersion or sprinkling.**—The fourth and last independent method of applying the water is by aspersion or sprinkling. This is merely applying the water to the plants and soil in the form of an artificial shower. It is only so applied in the smaller operations, such as market gardening or in the raising of berries. It is usually supplemented by other methods of irrigation, and the sprinkling method used only during certain seasons of the year to force the product, and when it would be injurious to use any of the other methods. At times pipes are strung along over the rows of plants pierced with small holes. These are then attached to a water system, where the water is under pressure, and the water is then forced through the holes out upon the plants. The method is valueless in general farm irrigation, and in horticulture, except in the case of the smaller fruits and berries.[1]

§ 38. **The drainage of irrigated lands, or lands affected by irrigation.**—The drainage of irrigated lands, and lands which lie below where irrigation operations are being carried on, has become almost as great a question from an economic standpoint, in

2 See The Storage of Winter Precipitation in Soils, by John A. Widtsoe, 1908, Bulletin No. 104, Experiment Station of the Agricultural College of Utah, Logan, Utah.

1 See The Primer of Irrigation, Anderson, 1905, p. 170.

many localities, as is the application of the water to the lands for irrigation. In the early history of irrigation, the lands adjoining the streams were first taken up and upon these irrigation operations were first commenced. These lands lying close to the natural stream required but little artificial drainage. But as time has gone on, the lands higher up and farther back from the stream were taken up and also irrigated. After this, it was found that the first farms were becoming too wet, caused by the seepage from the irrigation above them. This process has been repeated; and, as still higher lands were irrigated, in many instances, the first farms upon the lower lands have become practically swamps. It therefore naturally follows that, in order to develop these sections of the country to their full capacity, and not to retard their progress where they have been once developed, the question of the drainage of these lands has become one of great economic importance. In fact, the two questions of irrigation and drainage must go hand in hand where this condition exists. There are a number of good works upon the practical side of the subject to which reference is made in our note.[1] In this, as in other questions relating to the subject of irrigation, the United States Government has taken advanced steps in investigating and suggesting the remedy for this evil. See the many reports by the Agricultural Department upon the subject of irrigation and drainage investigations, catalogues of which may be secured from the Secretary, or from the Superintendent of Public Documents. The most of these reports are also available.[2] The State Agricultural Colleges and U. S. Experiment Stations throughout the West have also investi-

1 See Irrigation and Drainage, by F. H. King; Practical Farm Drainage, Elliott; Drainage for Profit and Health, Waring; Farm Drainage, French; Land Drainage, Miles; Tile Drainage, Chamberlain; The Primer of Irrigation, Anderson; Irrigation Engineering, Wilson; Articles upon the subject in *The Irrigation Age*. Any and all of the above works may be secured from *The Irrigation Age*, 30 North Dearborn Street, Chicago, Illinois.

2 See Drainage of Irrigated Lands, by Chas. F. Brown, Farmers' Bulletin No. 371.

See, also, Drainage of Farm Lands, by C. G. Elliott, Farmers' Bulletin No. 187; The Drainage of Irrigated Lands in the San Joaquin Valley, California, by Samuel Fortier and V. M. Cone, Office Experiment Stations, Bulletin No. 217; Report of Irrigation and Drainage Investigations, 1904, by Elwood Mead, Separate Doc. No. 799, same in Annual Report of the Office Experiment Stations for 1904; Development of Methods of Draining Irri-

gated the subject, especially with the object of remedying the evil in their particular States.[3]

This subject will also be discussed from a legal standpoint in this work.

§ 39. Legal rights of the irrigator and the owner of irrigation projects.—The last phase of the subject under discussion in this chapter, but by no means the least, is that relating to the legal rights of the irrigator, and the owner, projector of, or those who invest their money in all irrigation enterprises, or other projects dependent upon the use of water. Such persons should be thoroughly familiar with the laws upon the subject of the particular State where such operations are being, or are about to be, carried on. However, as a general proposition, it is not necessary to look further than the laws of that particular jurisdiction, as the control and regulation of the use of all waters flowing or lying within any State are left entirely to that State.[1]

Therefore, if the operator claims the right to the use of the water by virtue of an appropriation of the same under the Arid Region Doctrine of appropriation, he must understand thoroughly just what his rights are under the laws of the State for the acquisition of his right, and as against other appropriators, either prior or subsequent to him. If he is operating in one of those States which still adheres to the doctrine of the common law, he must

gated Lands, by C. G. Elliott, Doc. No. 1394, same in Annual Report of the Office of Experiment Stations for 1910; Losses of Irrigation Water and Their Prevention, by R. P. Teele, Annual Report of the Office of Experiment Stations for the year ending June 30, 1907, pp. 369-386; Work of Drainage Investigations, 1909-1910, by R. D. Marsden, Annual Report of the Office of Experiment Stations for the year ending June 30, 1910, pp. 43-54; Land Drainage by Means of Pumps, by S. M. Woodward, Drainage Engineer, Drainage Investigations, 1911, Bulletin No. 243, Office of Experiment Stations, U. S. Dept. of Agriculture.

[3] These bulletins may usually be had upon application.

Especially see Seepage or Return Waters from Irrigation, by Professor L. G. Carpenter, 1896, Bulletin No. 33, Colorado State Agricultural College Experiment Station, Fort Collins, Colorado; The Reclamation of Seeped and Alkali Lands, by C. F. Brown and R. A. Hart, 1910, Bulletin No. 111, Utah State Agricultural Experiment Station, Logan, Utah.

[1] For the right of a State to control the waters within its boundaries, see Sec. 593; see, also, Chap. 86.

also understand his rights as against those who own land through or adjoining which the stream flows, and who claim the right to the waters by virtue of their riparian ownership in and to the same. Again, if under the latter law, the operator claims the right to the use of the waters by virtue of his riparian rights accruing from the circumstances of the situation of his land upon the stream, he must understand the laws of the State relative to his right to divert the water from the natural stream, his rights as against his neighbors who have similar riparian rights, and who, perhaps, may insist that the water in the stream be permitted to flow in its natural channel, undiminished in quantity and undeteriorated in quality. And, where both rules of law are in force, he must also understand his rights as against those who claim the waters by appropriation, either made prior or subsequent to the time when he or his grantors first settled upon the land.[2] All these questions should be understood as thoroughly as possible before the operator invests too great a sum in the enterprise. The best advice which can be given upon this subject is for the operator to consult the best legal talent obtainable, prior to the time of commencing his operations; if it is done afterward, it may be that even the best counsel may not be able to extricate him from his difficulties. In many localities may be found the remains of works which have been constructed, or partially constructed, with great expenditure of money and labor, and which have been abandoned, from the simple fact that the projector did not understand his legal rights before he commenced operations. A prudent man will first take into consideration the legal phases of the enterprise before he embarks too deeply in the undertaking. And, by the careful consideration of these questions after taking legal advice, he may thus avert disaster to the enterprise, financial ruin to himself and those who invest in the project, and reflection upon the art of irrigation itself.

2 For riparian rights, see Chaps. 21-28, Secs. 450-551.

For irrigation as a riparian right, see Chap. 26, Secs. 498-525.

For the nature and extent of rights by appropriation, see Chap. 41, Secs. 757-774.

CHAPTER 2.

FORESTS AND THEIR RELATION TO STREAM FLOW.

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§ 62. The perpetuation of our forests—What has been done by the individual.

§ 40. Scope of chapter.—It is not our intention in this present chapter to give an extended discussion upon the general subjects of forests or forestry.[1] But the subject of forests is so closely allied to that of irrigation in the Western portion of this country, that this work would not be complete without a discussion of forests and their relation to stream flow. And, therefore, to this extent we will discuss the subject.[2]

1 That subject will be reserved for another work by the author, upon the subject of Forests, Forestry, and Forest Laws. This work is in a large measure written, and will be published shortly after the publication of the present work.

2 For economic questions relating to irrigation and methods, see Chap. 1, Secs. 1-39.

§ 41. Our forest resources.—The United States ranks second among the nations of the world in the extent of its forests. Russia, including Siberia, has the largest forest area of any country, while Canada ranks third.[1] It is estimated that the original forests of the United States covered not less than 850,000,000 acres. All classes of our forests, good, bad, and indifferent, now cover but 550,000,000 acres, the difference of 300,000,000 acres having been destroyed by various means, mainly through the march of civilization.[2] Of the 550,000,000 acres remaining, there are but 225,000,000 acres which are called "producing forests"; and on this area the stand is so open that all the trees could be grown on 145,000,000 acres.[3] Of the forested area of the country about one-fifth is owned by the Government and by States, and about four-fifths is owned by private parties.[4] The area of such lands owned by the Federal Government is approximately 92,629,500 acres, of which 81 per cent is in National forests, 11 per cent in Indian reservations, and 5 per cent in unreserved public lands.[5] The total area of State forested land is estimated at 9,460,622 acres.[6] Of the four-fifths of such lands owned by private parties, it is estimated that in the whole United States the farmers own over 204,000,000 acres, of which 46 per cent contains merchantable timber, 43 per cent cord-wood timber, and 11 per cent brush land.[7] The re-

1 Foreign Sources of Timber Supply, by Raphael Zon of the U. S. Forest Service, Vol. 2, p. 280, Report of the National Conservation Commission, 1909; see, also, authorities cited on p. 369.

2 For the destruction of forests, see Sec. 43.

3 Methods of Increasing Forest Productivity, by E. E. Carter, U. S. Forest Service, Vol. 2, p. 279, Report of the National Conservation Commission, 1909.

4 Article on Forests, by Overton W. Price, Secretary, Section of Forests, Vol. 1, p. 52, Report of the National Conservation Commission, 1909; same in Cir. No. 171, Forest Service, U. S. Dept. of Agriculture.

5 Standing Timber in the Possession of the Federal Government, by G. M. Homans, U. S. Forest Service, Vol. 2, p. 192, same Report as last above.

For the total area of all lands reserved as National Forests, see Sec. 643.

6 Standing Timber Owned by States, by J. Girvin Peters, U. S. Forest Service, Vol. 2, p. 191, same Report as last above.

7 Standing Timber in Wood Lots, by Wesley Bradfield, U. S. Forest Service, Vol. 2, p. 181, same Report as last above.

maining of the forested area in the United States is in the hands of railways, lumbermen, timbermen, and speculators.[8]

§ 42. **Forest growth and methods of increase.**—The estimated total production by forest growth of the total forested area of the United States, including mature and devastated forests, is placed at 6,700,000,000 cubic feet. This is an average of about 28 cubic feet per acre for the estimated "producing forests,"[1] and about 12 cubic feet for the entire forest and woodland area of the United States, including all classes of forest lands.[2]

In carefully managed forests, such as are found in Germany and some of the other countries of Europe, the annual cut is equal to the growth or increase in wood material, and, therefore, for such a forest productiveness means both growth and the amount cut. And the technical term "producing forests," as used by foresters, does not merely mean forests from which timber and wood may be obtained, but it means those forests, wherein the quantity cut in a given period is equaled by the growth of the wood material during the same period. The productivity of our forest area may be increased in many ways. The removal of the mature timber will give an opportunity for the younger trees already on the land to grow to maturity. These trees may then be cut, and the process thus continued indefinitely. The vacant spaces on lands now designated as forest may be planted to trees, and thereby the density increased without injury to the other portions. Fast growing species may also be either retained or planted. The quality of the timber and lumber produced may be increased by the retention of naturally well-shaped and large growing trees only. And it is estimated that, from all sources, the productivity of our present forest area may be increased from the annual average of 12 cubic feet to that of 80 cubic feet, and from the

[8] See, also, Original Forests, by R. S. Kellogg, U. S. Forest Service, Vol. 2, p. 179, same report as last above.

[1] See Secs. 58-62.

[2] Rate of Forest Growth, by E. A. Ziegler, U. S. Forest Service, Vol. 2, p. 223, Report of the National Conservation Commission, 1909.

"The yearly growth of wood in our forests does not average more than twelve cubic feet per acre. This gives a total yearly growth of less than 7,000,000,000 cubic feet."—Forests, by Overton W. Price, Secretary, Section of Forests, Vol. 1, p. 54, Report of the National Conservation Commission, 1909.

total of 6,700,000,000 cubic feet to 25,850,000,000 cubic feet.[3] But, as we shall see in the following section,[4] in our forests as managed and operated at the present time, the actual cut for legitimate purposes far exceeds the present growth, not taking into consideration the losses from waste, including fires.[5] "We are now cutting annually the growth of many past years."[6] In a properly maintained "civilized forest" only the ripe timber is cut, and great care taken to preserve the young growth from injury.[7] By this method a perpetual growth and supply of timber is maintained.

§ 43. The destruction of our forests.—The causes of the destruction of our forests are numerous and are principally as follows: We are taking from our forests annually for legitimate uses 23,000,000,000 cubic feet of wood, including waste in logging and manufacturing, as against 7,000,000,000 cubic feet grown upon

[3] See Rate of Forest Growth, by E. A. Ziegler, U. S. Forest Service, Vol. 2, pp. 203-269, Report National Conservation Commission, 1909; Methods of Increasing Forest Productivity, by E. E. Carter, U. S. Forest Service, Vol. 2, pp. 270-279, same Report; Forest Products, by R. S. Kellogg, U. S. Forest Service, Vol. 2, pp. 196-202, same Report; Foreign Sources of Timber Supply, by Raphael Zon, U. S. Forest Service, Vol. 2, pp. 280-370, and authorities cited on pp. 369, 370, same Report; Cost of Forestry in Different Countries, by Professor H. S. Graves of Yale Forest School, Vol. 2, pp. 371-374, same Report; Extent to Which Foreign Methods of Forest Administration Are Suited to the Conditions in the United States, by S. T. Dana, U. S. Forest Service, Vol. 2, pp. 375-389, same Report; Forest Products of the United States, 1906, Bulletin No. 77, Forest Service, U. S. Dept. of Agriculture, Gifford Pinchot, Forester.

See, also, authorities cited under Sec. 43.

See, also, the annual reports of the Superintendent of Forestry of the Dominion of Canada, issued by the Department of the Interior, Ottawa, giving full details as to the care and regulations of the forests in the Dominion, including the planting of new forests.

[4] See Sec. 43.

[5] For the destruction of forests by fires, see Sec. 43.

[6] Methods of Increasing Forest Productivity, by E. E. Carter, *supra*, p. 270.

[7] See the Indian Forest Act of British India, 1878; Imperial Gazetteer of India, Simla, 1903, Vol. 3, Chap. 2; Circular No. 22-F, dated Oct. 19, 1894, issued by the Dept. of Revenue and Agriculture of the Government of India.

See Review of Forest Administration in British India for the year 1903-4, with a quinquennial summary; also review for year 1905-6, both by S. Eardley-Wilmot, Inspector General to the Government of India, Calcutta, 1906, 1907.